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(54) PRIVATE/RESIDENTIAL CODE DIVISION MULTIPLE ACCESS WIRELESS COMMUNICATION SYSTEM

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(22) Filed: **Nov. 5, 1998**

Related U.S. Application Data

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(51) **Int. Cl.**[7] **H04B 7/216**

(52) **U.S. Cl.** **370/335**; 455/403

(58) **Field of Search** 370/335, 342, 370/336, 203, 252, 229, 441, 515, 310, 320, 328, 479; 455/403, 426, 447

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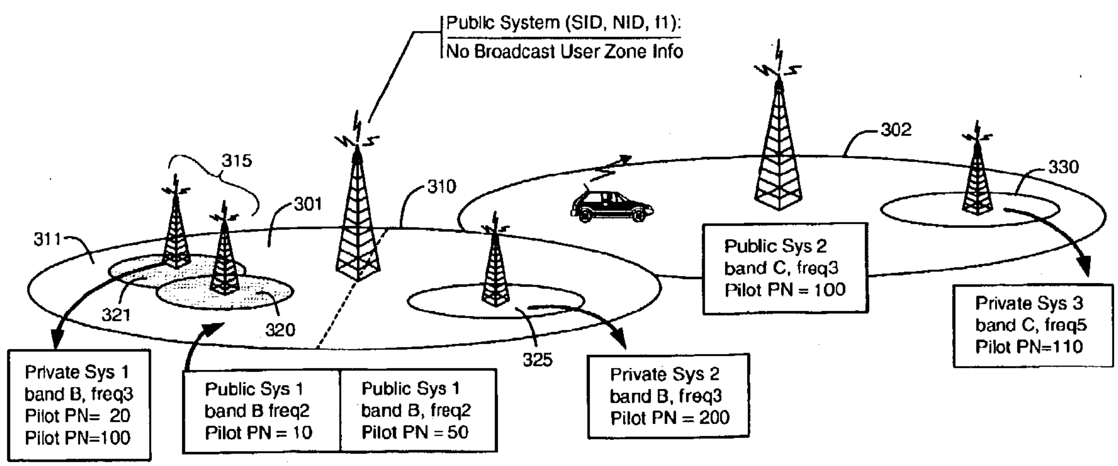
(57) **ABSTRACT**

The private/residential wireless communication system uses the code division multiple access air interface to provide communication with radiotelephones. The present invention provides support for both physical and virtual private systems. A radiotelephone monitors the broadcast channel of the public system to obtain private system information. The radiotelephone use the broadcast information together with pre-programmed stored private system information in the radiotelephone memory to acquire and register with the private systems. If the radiotelephone locates a private system that is not stored in its memory, it obtains relevant information for registering with that system. The radiotelephone then stores the information of accepting systems. This information is displayed so that a system can be chosen. The radiotelephone then registers with the chosen system.

15 Claims, 8 Drawing Sheets



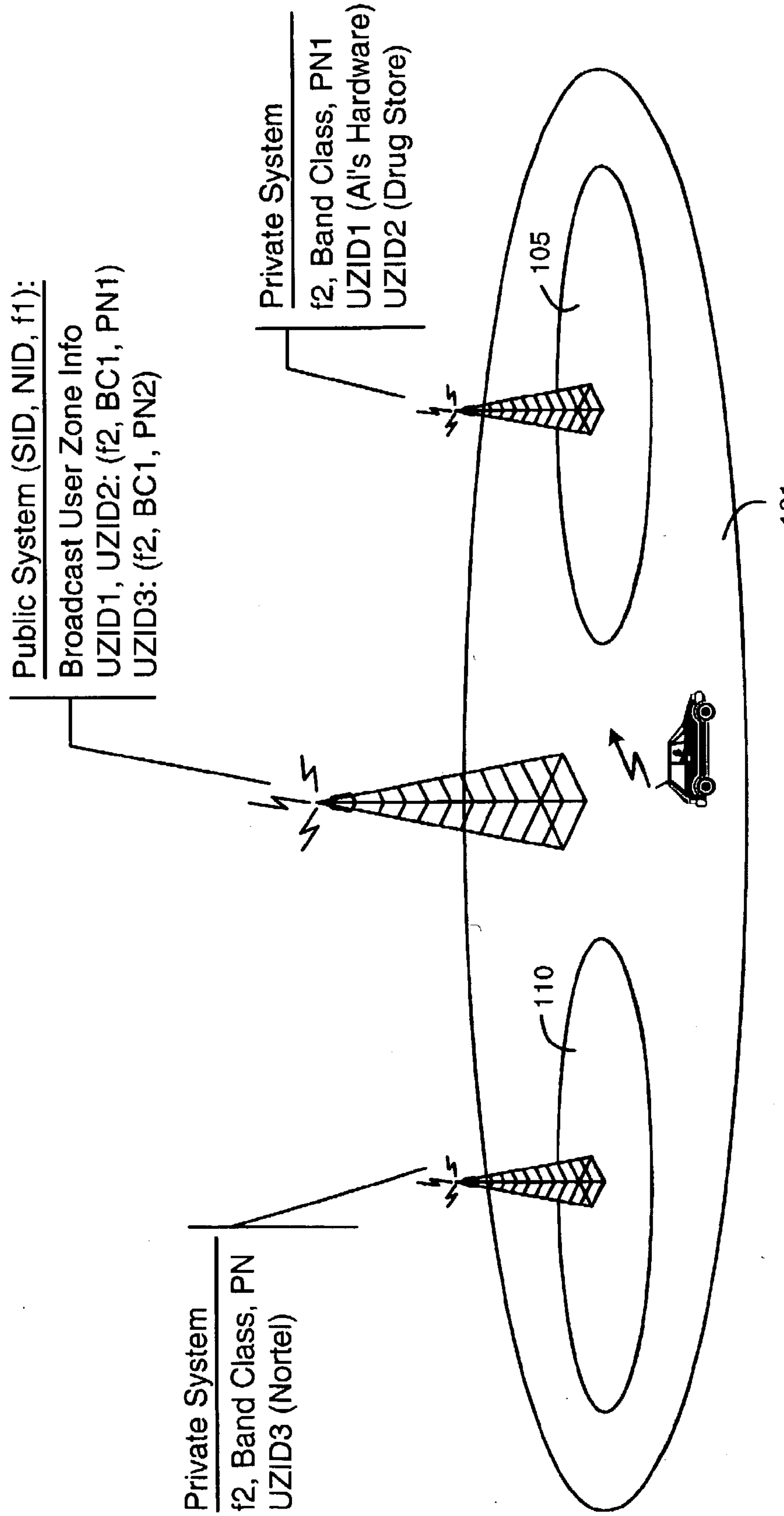

Public System (SID, NID, f1):
Broadcast User Zone Info
UZID1, UZID2: (f2, BC1, PN1)
UZID3: (f2, BC1, PN2)
Private System
f2, Band Class, PN1
UZID1 (Al's Hardware)
UZID2 (Drug Store)
105
101
110
Private System
f2, Band Class, PN
UZID3 (Nortel)

FIG. 1

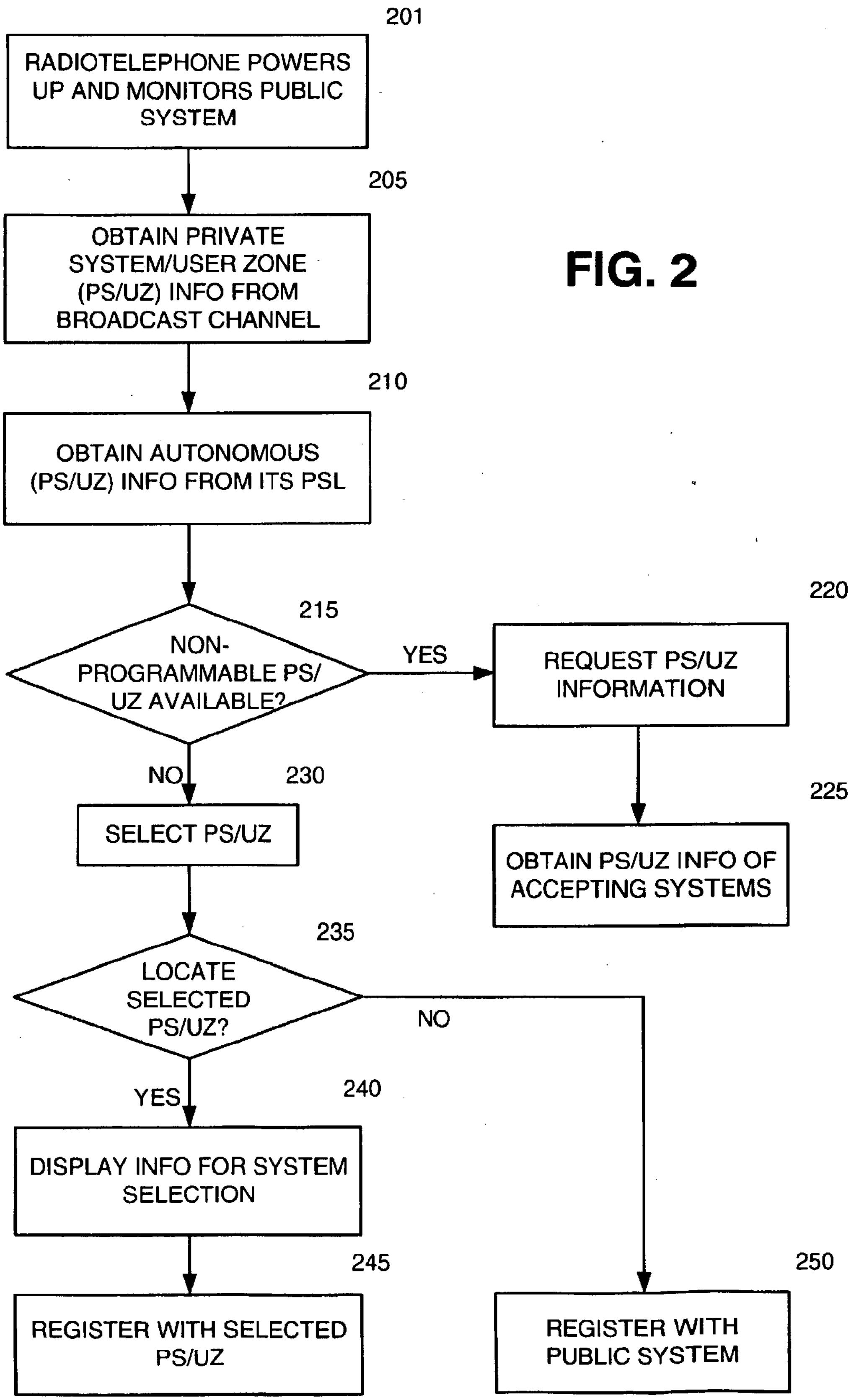

201
RADIOTELEPHONE POWERS UP AND MONITORS PUBLIC SYSTEM
205
OBTAIN PRIVATE SYSTEM/USER ZONE (PS/UZ) INFO FROM BROADCAST CHANNEL
210
OBTAIN AUTONOMOUS (PS/UZ) INFO FROM ITS PSL
215
NON-PROGRAMMABLE PS/UZ AVAILABLE?
YES
220
REQUEST PS/UZ INFORMATION
225
OBTAIN PS/UZ INFO OF ACCEPTING SYSTEMS
NO
230
SELECT PS/UZ
235
LOCATE SELECTED PS/UZ?
NO
YES
240
DISPLAY INFO FOR SYSTEM SELECTION
245
REGISTER WITH SELECTED PS/UZ
250
REGISTER WITH PUBLIC SYSTEM

FIG. 2

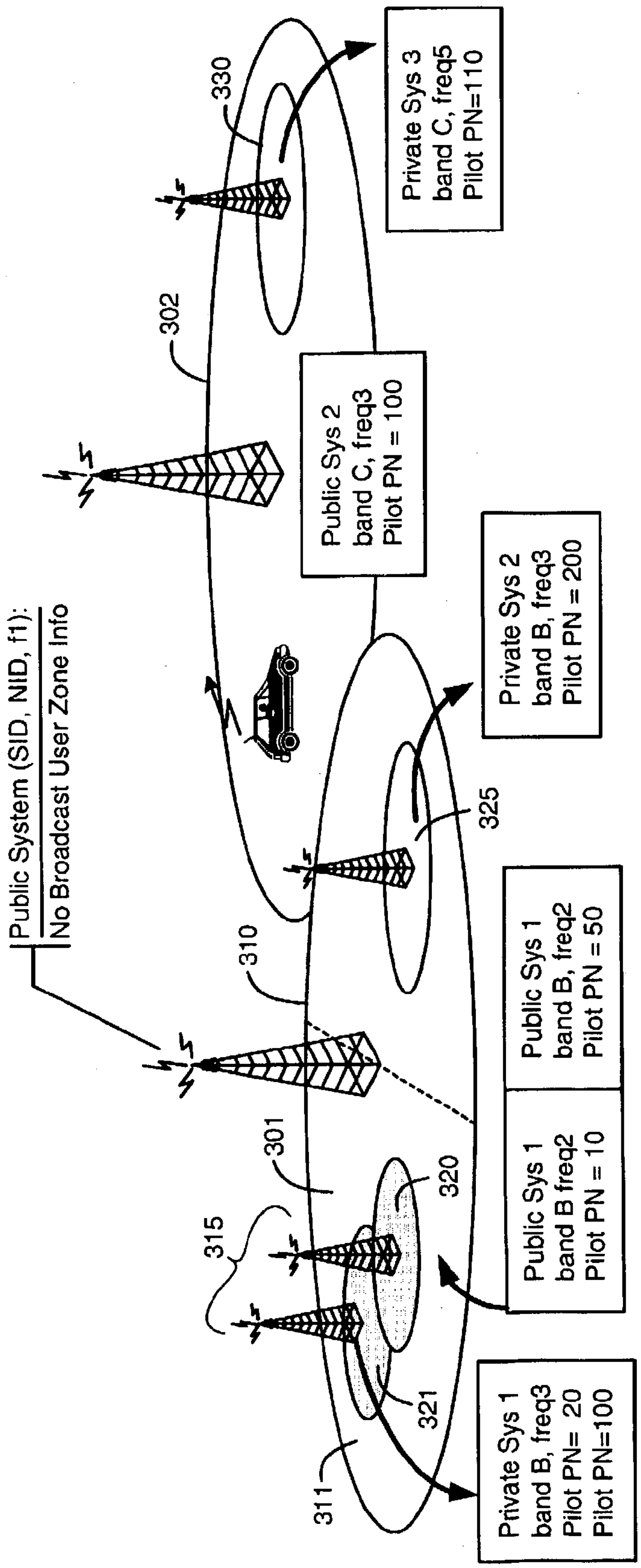

Public System (SID, NID, f1):
No Broadcast User Zone Info
Private Sys 3
band C, freq5
Pilot PN=110
330
302
Public Sys 2
band C, freq3
Pilot PN = 100
Private Sys 2
band B, freq3
Pilot PN = 200
325
310
Public Sys 1
band B, freq2
Pilot PN = 50
301
Public Sys 1
band B freq2
Pilot PN = 10
315
320
321
311
Private Sys 1
band B, freq3
Pilot PN= 20
Pilot PN=100

FIG. 3

Overlaying System Table (OST)							
	SID	NID	BASDE_ID	BS LAT/LONG	BAND CLASS	Frequ-ency	Pointer to PST
1	SID1	NID1	BASE_ID1	LAT1/LONG1	B	F2	00001
2	SID1	NID1	BASE_ID2	LAT2/LONG2	B	F2	00010
3	SID2	NID2	BASE_ID3	LAT3/LONG3	C	F3	00011

Figure 4A

PRIVATE SYSTEM TABLE (PST)				
Index	BAND CLASS	Frequency	Pilot-PN	Location Info
00001	B	F4	PN-20	(LAT1/LONG1/RAD1)
			PN-100	
00010	B	F4	PN-200	(LAT1/LONG1/RAD1)
00011	C	F5	PN-110	(LAT1/LONG1/RAD1)

Figure 4B

SYSTEM IDENTIFICATION TABLE (SIT)		
1	UZID1	Alpha Tag 1
2	UZID2	Alpha Tag 2
3	UZID3	Alpha Tag 3
4	UZID4	Alpha Tag 4
5	UZID5	Alpha Tag 5

Figure 4C

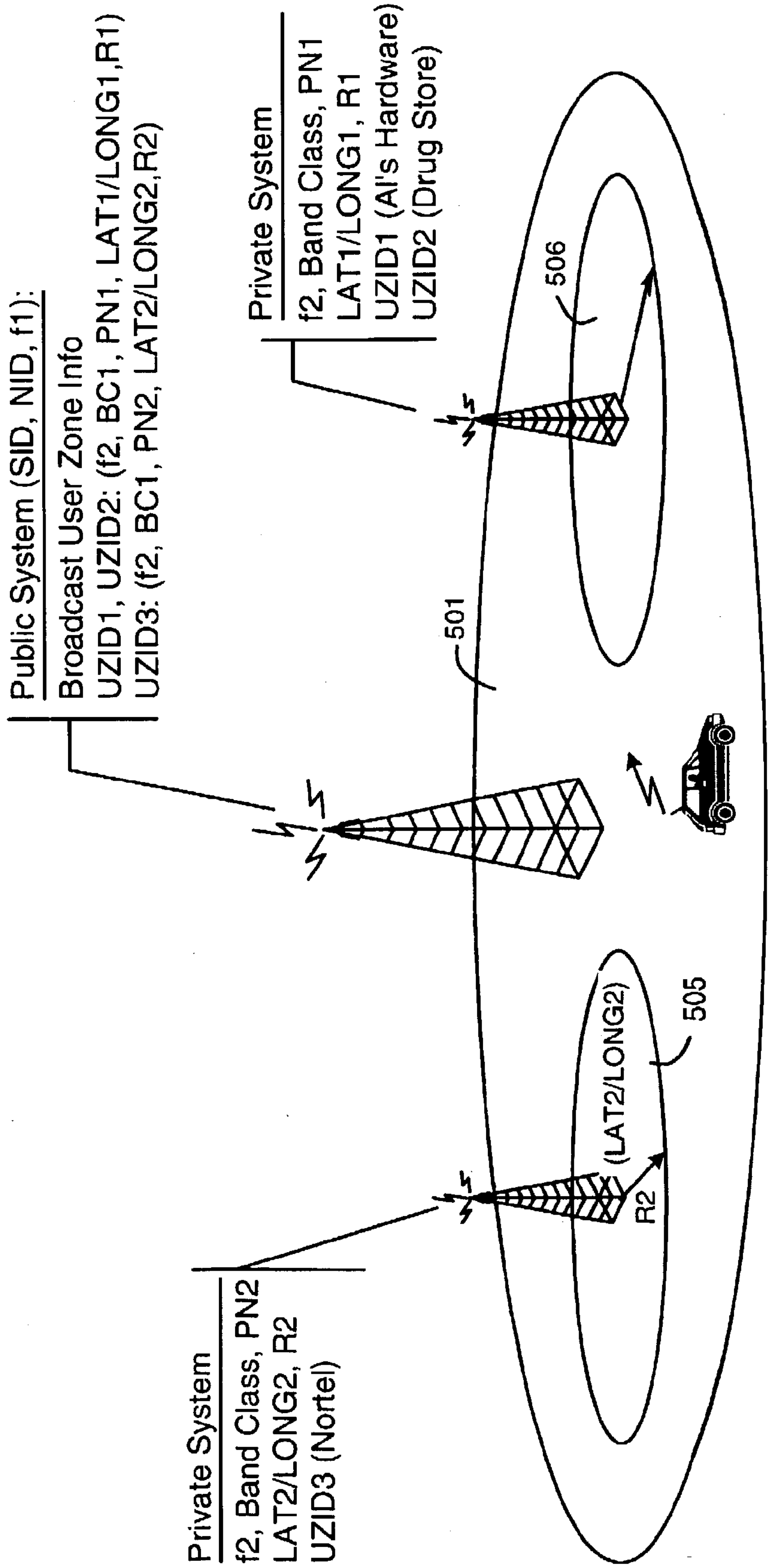
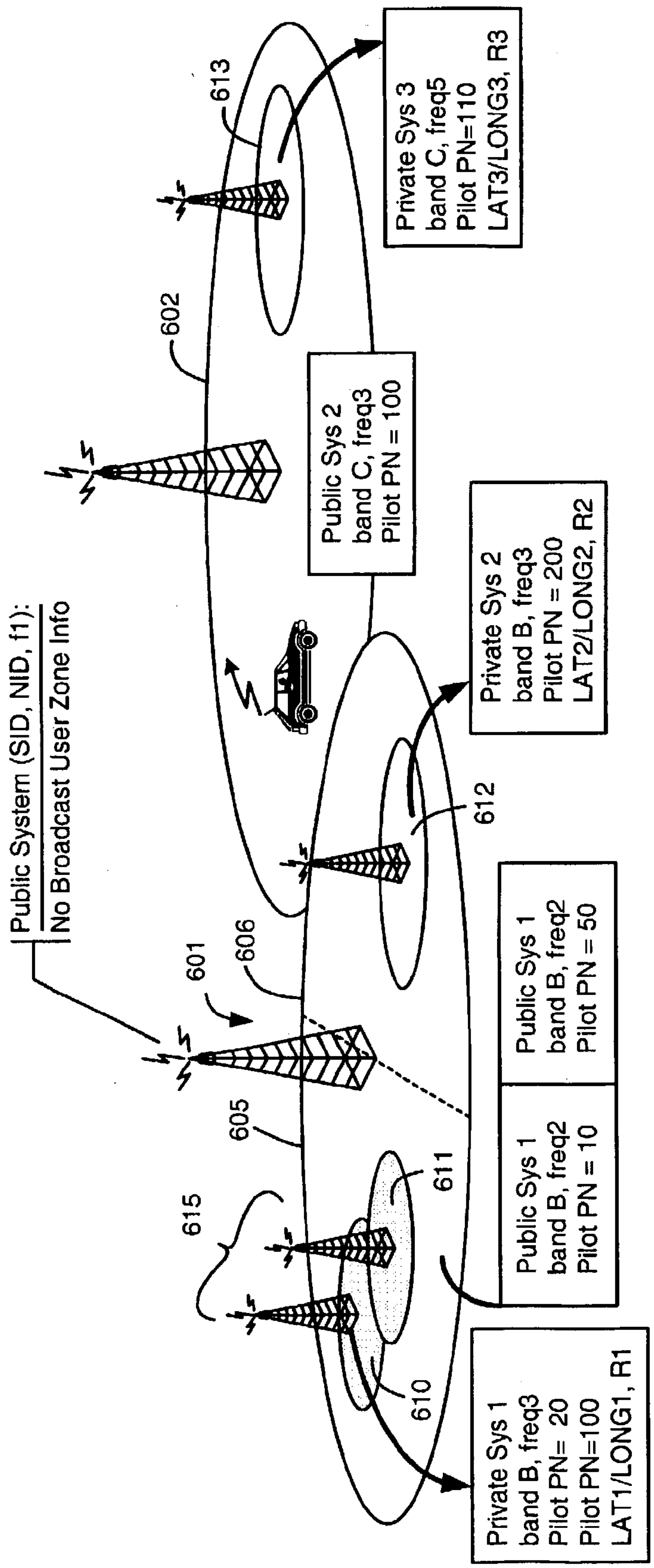

Public System (SID, NID, f1):
Broadcast User Zone Info
UZID1, UZID2: (f2, BC1, PN1, LAT1/LONG1,R1)
UZID3: (f2, BC1, PN2, LAT2/LONG2,R2)
Private System
f2, Band Class, PN1
LAT1/LONG1, R1
UZID1 (Al's Hardware)
UZID2 (Drug Store)
506
501
505
(LAT2/LONG2)
R2
Private System
f2, Band Class, PN2
LAT2/LONG2, R2
UZID3 (Nortel)

FIG. 5



Public System (SID, NID, f1):
No Broadcast User Zone Info
601
602
605
606
610
611
612
613
615
Private Sys 3
band C, freq5
Pilot PN=110
LAT3/LONG3, R3
Public Sys 2
band C, freq3
Pilot PN = 100
Private Sys 2
band B, freq3
Pilot PN = 200
LAT2/LONG2, R2
Public Sys 1
band B, freq2
Pilot PN = 50
Public Sys 1
band B, freq2
Pilot PN = 10
Private Sys 1
band B, freq3
Pilot PN= 20
Pilot PN=100
LAT1/LONG1, R1

FIG. 6

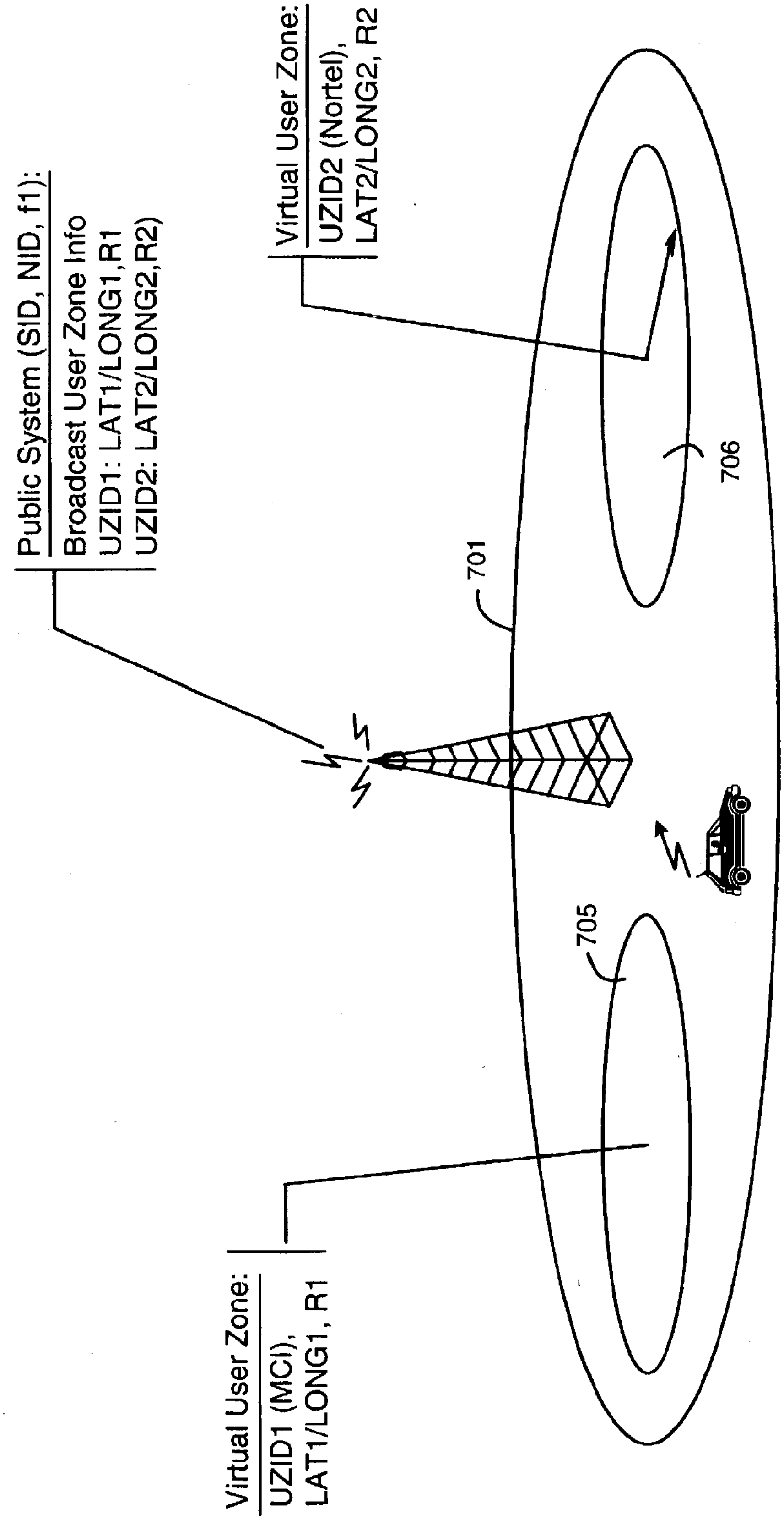

Public System (SID, NID, f1):
Broadcast User Zone Info
UZID1: LAT1/LONG1,R1
UZID2: LAT2/LONG2,R2
Virtual User Zone:
UZID2 (Nortel),
LAT2/LONG2, R2
Virtual User Zone:
UZID1 (MCI),
LAT1/LONG1, R1
701
705
706

FIG. 7

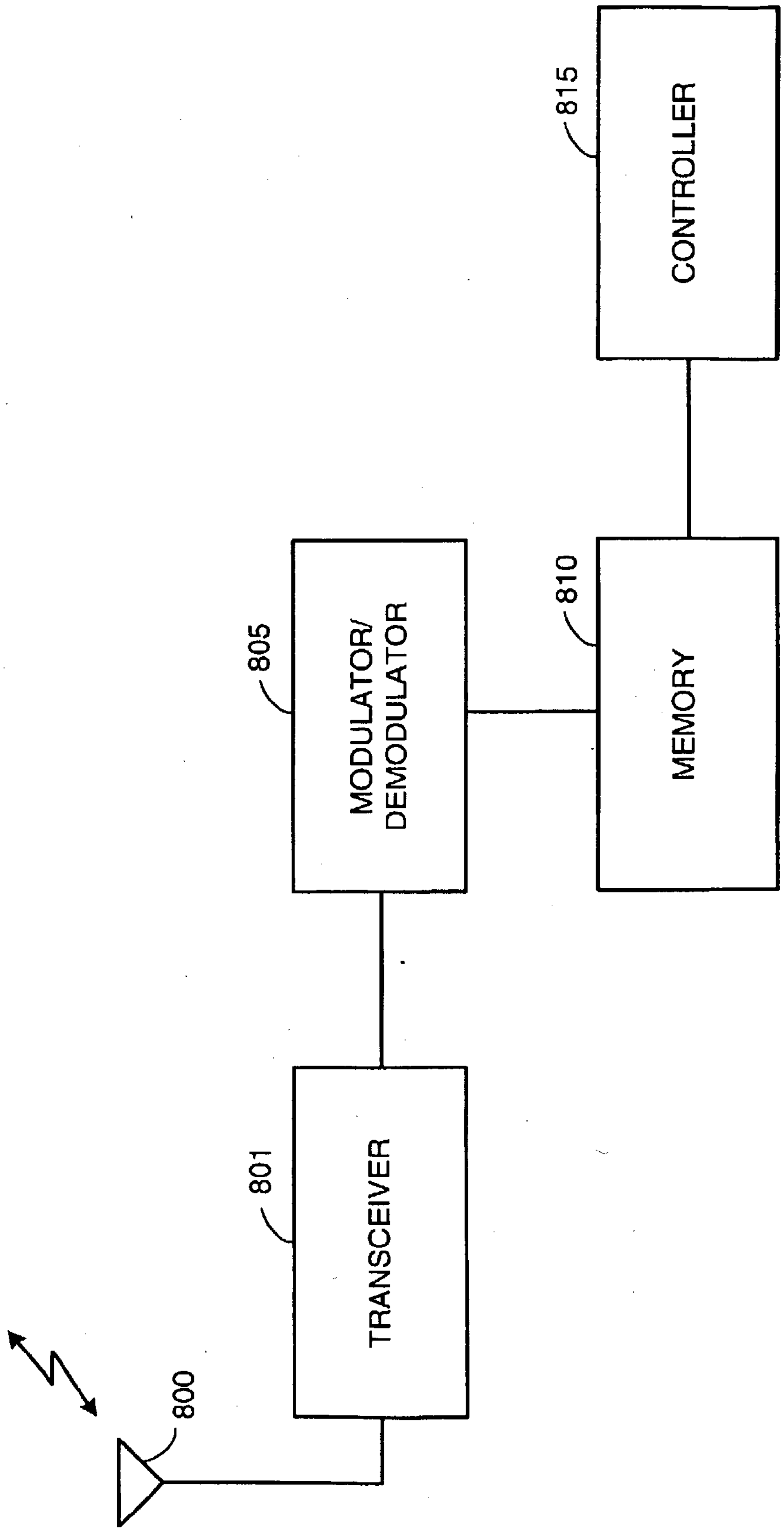

815
CONTROLLER
810
MEMORY
805
MODULATOR/
DEMODULATOR
801
TRANSCEIVER
800

FIG. 8

PRIVATE/RESIDENTIAL CODE DIVISION MULTIPLE ACCESS WIRELESS COMMUNICATION SYSTEM

RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/064,868, filed Nov. 5, 1997.

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to radio communications. More particularly, the present invention relates to a private code division multiple access (CDMA) wireless communications system as well as CDMA Tiered Service capability.

II. Description of the Related Art

Multiple access modulation techniques are efficient techniques for utilizing the limited radio frequency spectrum. Examples of such techniques include time division multiple access (TDMA), frequency division multiple access (FDMA), and code division multiple access (CDMA).

CDMA modulation employs a spread spectrum technique for the transmission of information. A spread spectrum system uses a modulation technique that spreads the transmitted signal over a wide frequency band. This frequency band is typically substantially wider than the minimum bandwidth required to transmit the signal.

A form of frequency diversity is obtained by spreading the transmitted signal over a wide frequency range. Since only part of a signal is typically affected by a frequency selective fade, the remaining spectrum of the transmitted signal is unaffected. A receiver that receives the spread spectrum signal, therefore, is affected less by the fade condition than a receiver using other types of signals.

The spread spectrum technique is accomplished by modulating each base band data signal to be transmitted with a unique wide band spreading code. Using this technique, a signal having a bandwidth of only a few kilohertz can be spread over a bandwidth of more than a megahertz. Typical examples of spread spectrum techniques are found in M. K. Simon, Spread Spectrum Communications, Volume I, pp. 262–358.

In a CDMA-type wireless communication system, multiple signals are transmitted simultaneously at the same frequency. A particular receiver then determines which signal is intended for that receiver by a unique spreading code in each signal. The signals at that frequency, without the particular spreading code intended for that particular receiver, appear to be noise to that receiver and are ignored.

The present CDMA air interface, however, is not well suited to private systems. A private system that uses the public CDMA carrier is required to provide soft hand-off support to public users in its coverage area to avoid RF interference issues. The reason is that when a radiotelephone, operating on the macro public system, moves closer to the private micro-cell, it creates interference to the micro-cell users. It is thus imperative for the private micro-cell to be able to control the power of that radiotelephone (i.e. support of hand-off); otherwise, interference becomes so strong that it makes the private micro-cell inoperative.

In a single carrier deployment, therefore, RF interference limits the feasibility of private home and office CDMA systems. There is a resulting unforeseen need for a private wireless communication system using a CDMA air interface. As a result it is almost impossible for CDMA systems to support private systems on the same RF carrier frequency as the overlaying public system. Furthermore, service providers cannot have geographic granularity of billing and other services for a region that is smaller than a natural CDMA cell or sector. There is accordingly a need for a new scheme to provide the capability of a private/residential system services, as well as tiered services in CDMA wireless communication systems.

SUMMARY

The present invention encompasses a private/residential wireless communication system that uses a code division multiple access air interface. The private system is overlaid by a public CDMA system. The public CDMA system comprises an antenna coupled to a base station. The private system may operate on a predetermined frequency, or it may share the same radio resources with the overlaying public system. The private system may be assigned a predetermined identification (for example User Zone identification UZID). When the private system operates on a different frequency than the overlaying public system, the private system may be assigned one (or more) predetermined User Zone(s) identification.

In certain embodiments, the public base station broadcasts the predetermined identification over a channel for reception by a radiotelephone. This instructs the radiotelephone as to what private systems are being served by the public system.

In alternate embodiments, the public system also broadcasts frequency, band class, pseudorandom noise offset information, and geographical location information regarding the private systems that are served by the public system. If the radiotelephone has the ability to determine its geographic location, it can find the private systems by using the broadcast geographic information.

In alternate embodiments, the private system is autonomous to the public system and no information regarding the private system is broadcast by the public system.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a private carrier embodiment of the present invention using non-autonomous User Zones and an RF dependent search scheme.

FIG. 2 shows a flowchart of the system selection process of the present invention.

FIG. 3 shows another alternate embodiment of the present invention using autonomous User Zones and an RF dependent search scheme.

FIGS. 4A–C show an example of a Private System List in accordance with the system of FIG. 3.

FIG. 5 shows another alternate embodiment system of the present invention using non-autonomous User Zones and a location dependent search scheme.

FIG. 6 shows another alternate embodiment of the present invention using autonomous User Zones and a location dependent search scheme.

FIG. 7 shows another alternate embodiment of the present invention using a public carrier and virtual User Zones.

FIG. 8 shows a radiotelephone of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention provides private, semiprivate, and residential system capability using a CDMA air interface. The present invention also provides tiered service capability

in CDMA systems. Tiered service provides the operator with the ability to use existing networks to offer custom services to one or more subscribers based on their geographic location. A radiotelephone operating in such a system is provided one-number, seamless communication in any environment having the infrastructure.

The present invention provides the support of both physical private systems and virtual private systems. A physical private system operates on a different carrier frequency than the overlaying public system using independent radio resources. A virtual private system operates on the same carrier frequency of the overlaying public system. In this case, the virtual private system users share the same resources with the public user, however are offered customized services.

Subsequent discussions refer to the communications device as a radiotelephone. The present invention is not limited to a radiotelephone but can include any wireless communication device such as a computer with wireless communication capability.

The communication system of the present invention implements User Zones to provide seamless communication between different types of systems and to support both physical and virtual private systems. The User Zones are a customer subscription option offered to a select group of users. A specific User Zone is associated with a set of features and/or services plus a geographic area in which the User Zone features/services are made available to the customers that have subscribed to that particular User Zone.

The boundary of the geographic area of the User Zone may be established based on the coverage area of a public or private base station or it may be established independent of RF topology. In the latter embodiment, a process for the radiotelephone to determine its location, such as using the global positioning system (GPS) or triangulation, is employed to determine if it is operating within a particular User Zone. Alternate embodiments use other methods for determining if the radiotelephone is operating in a particular User Zone. These include, but are not limited to, the radiotelephone user inputting the location information and using time of arrival of signals.

An example of a User Zone is a department store. The boundaries of the User Zone would be the department store building and the immediate area surrounding the store. The store can then transmit the latest sale information to shoppers. Additionally, the store management can use the User Zone to communicate with its employees who are equipped with radiotelephones.

Another example will be a private campus. If the user stays in the area covered by the User Zone, then he may get a set of features and services such as 4-digits PBX-type dialing. Furthermore, the user may be billed at a flat rate on a monthly basis independent of the actual usage of the radiotelephone.

The User Zones of the present invention can be supported in various ways. One embodiment defines User Zones that operate on private radio equipment that is separate from the radios of the public serving base station but still supported by the public base station. User Zones of this embodiment are listed on the broadcast public paging channel neighbor lists and are subsequently referred to as non-autonomous private User Zones.

Another embodiment defines User Zones that operate on private radio equipment not supported by the public base station. User Zones of this embodiment are not listed on the broadcast public paging channel neighbor lists and are subsequently referred to as autonomous private User Zones.

Still another embodiment defines User Zones that shares the radio resources with the public system. The User Zones of this last embodiment are subsequently referred to as virtual User Zones. The broadcast public paging channel broadcasts the User Zones identification (UZID) of the virtual private User Zones.

In certain embodiments, to identify a User Zone, the network's base station transmitter broadcasts User Zone information. This information varies depending on the embodiment. In the case of virtual private User Zones, the User Zone information can include the User Zone identification numbers (UZID) of the User Zones that are supported by the serving base station. In the case of non-autonomous private User Zones, the User Zone information may include: the band class and frequency on which the private system supporting a particular User Zone operates, as well as the pseudorandom noise (PN) offset of the associated pilot. In addition, the User Zone information may include User Zone boundary specification parameters, for example the latitude and longitude coordinates of the center of each User Zone in the network, and the radius of each User Zone. In the preferred embodiment, the User Zone information is transmitted on the paging channel of the serving base station. Alternate embodiments may use other channels to transmit the information.

After the radiotelephone receives the broadcast User Zone information, the radiotelephone needs to determine if it is in one of the User Zones to which it has subscribed for service. In subsequent access back to the system, the radiotelephone, in addition to normal operational procedures, needs to identify its User Zone to the system.

Furthermore, based on the received User zone information, the radiotelephone can query the system on whether it can subscribe to certain User Zones, unknown to the radiotelephone, that are broadcast by the serving base station. In response to the query, the base station identifies to the radiotelephones the User Zones accepting subscription and registration. The serving base station also sends all the associated information necessary for the radiotelephone to get service from a particular User Zone.

In the preferred embodiment, the radiotelephone retains accepted User Zone ID information in memory through a power cycle. In other words, once the radiotelephone is powered down, the information is lost. In alternate embodiments, the information can be retained in non-volatile memory for future use. This non-volatile memory includes removable memory cards as well as memory internal to the radiotelephone.

In subsequent discussions of wireless communication systems of the present invention, each example shows one or two User Zones. This is for illustration purposes only. Additionally, the following embodiments discuss particular frequencies, PN offsets, band classes, latitudes/longitudes, and radiuses of private systems. These are also for illustration purposes only and do not limit the invention to the values discussed.

FIG. 1 illustrates a private carrier, non-autonomous User Zone wireless communication system using an RF dependent search scheme. This system is comprised of a public system (**101**) and two private systems (**105** and **110**). The public system (**101**) operates on frequency f1 while the two private systems (**105** and **110**) operate on frequency f2.

In this embodiment, the private systems (**105** and **110**) are assigned to three separate businesses. One private system (**105**) comprises two User Zones where each zone is assigned to a department store. The other private system

(110) is comprised of a single User Zone assigned to an office building.

The public system's serving base station transmits, on the paging channel, the information required to identify the private systems. In this embodiment, the information includes the User Zone ID number (UZID1, UZID2, and UZID3). Each User Zone ID is assigned to a different business. In this embodiment, UZID1 is assigned to "Al's Hardware Store", UZID2 is assigned to "Drug Store", and UZID3 is assigned to "NORTEL".

Along with the UZID, the serving base station broadcasts the frequency, band class (BC), and PN offset assigned to each private system. For example, private system (105) is assigned to frequency f2, BC1, and PN1. Private system (110) is assigned to frequency f2, BC1, and PN2.

When the radiotelephone powers up or enters the coverage area of a public system base station, it obtains the overlaying private system information off the paging channel. If the user prefers one of the private systems and a UZID match occurs, the radiotelephone attempts to locate the private system radio by tuning to the band class and frequency of the private system.

The radiotelephone then searches for the pilot using the broadcast PN offset assigned to the desired User Zone. If the radiotelephone finds the private system, it displays the corresponding alphanumeric tag (e.g., "Al's Hardware Store", "Drug Store", and "NORTEL") to the user and registers with the private system.

FIG. 3 illustrates a private carrier, autonomous User Zone system that uses an RF dependent search scheme. The system of FIG. 3 illustrates two public systems (301 and 302). Public system 1 (301) is split into two sectors (310 and 311). Each sector (310 and 311) of the public system has a different PN offset: 10 (311) and 50 (310).

Public system 1 (301) overlays two private systems (315 and 325). The private systems (315 and 325) operate on the same frequency, f3, and the same band class, BC, but on a different frequency from the overlaying public system (301). The private systems (315 and 325), however, operate on a different frequency from the overlaying public system (301) frequency, f2.

One private system (315) is comprised of two base stations (320 and 321) having different PN offsets 20 (320) and 100 (321). The other private system (325) is comprised of one base station having PN offset 200.

An example of such a system is a multiple floor office tower. Each floor of the tower may have a different base station or multiple base stations, depending on the coverage of each base station and the floor layout. In one embodiment, each base station is assigned a different PN offset. Public system 2 (302) overlays a third private system (330). The underlaying third private system (330) has a different frequency, f5, from the overlaying public system (302). The private system (330) also has a PN offset of 110. In the embodiment of FIG. 3, the base stations of the overlaying public systems do not broadcast the private system information. Radiotelephones subscribed to autonomous private systems use a Private System List or Preferred Roaming List that is stored in the radiotelephone to assist it in finding the autonomous private system.

In this embodiment, the Private System List is comprised of three tables, illustrated in FIGS. 4A–C. These tables are the Overlaying System Table, the Private System Table, and the System Identification Table. Alternate embodiments use different quantities of tables containing similar information or any other information required for that particular embodiment.

The Overlaying System Table, illustrated in FIG. 4A, contains the overlaying public system information, such as the system ID (SID), network ID (NID), base station ID (Base_ID), base station longitude and latitude (LAT/LONG), frequency (f), and band class. This table also provides pointers to the Private System Table.

The Private System Table, illustrated in FIG. 4B, holds the band class, frequency, and pilot PN offsets of the autonomous private radio system. The PN offset enables the radiotelephone to begin searching for the private system. The Private System Table may also hold private system location determination parameters.

The System Identification Table, illustrated in FIG. 4C, holds the User Zone IDs and alphanumeric tags of the private systems.

The radiotelephone determines that it is in the vicinity of the private system of interest when a match occurs between the broadcast public system information and that stored in the overlaying system table. If this occurs, the radiotelephone may start to acquire the private system using parameters specified in the private system table. The radiotelephone stays in the private system and gets service when the acquisition is successful. If the radiotelephone fails to acquire any of the private systems, it stays in the current system and starts the acquisition process again at a later time.

FIG. 5 illustrates a private carrier, non-autonomous User Zone system that uses a location dependent search scheme. In this embodiment, multiple User Zone IDs are broadcast on the paging channel to identify the private systems supported by the serving base station. Additionally, the serving base station broadcasts the appropriate frequency, band class, PN offset, location of the supported private systems in degrees of latitude and longitude, and the radius of the private systems. In alternate embodiments, other private system boundary specification parameters can be broadcast.

The system illustrated in FIG. 5 is comprised of one public system (501) that overlays two private systems (505 and 506). One of the private systems (506) comprises two User Zones that are assigned UZID1 and UZID2. This private system (506) operates on frequency f2, different from the overlaying public system (501), and assigned PN offset PN1.

The other private system (505) is comprised of a single User Zone that is assigned UZID3. Similar to the other private system (506), this private system (505) also operates on frequency f2, different from the overlaying public system (501), and assigned PN offset PN2.

When the radiotelephone enters the coverage area of the public system's (501) base station, it obtains the private system information off the paging channel. If a User Zone ID match occurs with an authorized User Zone ID stored in the radiotelephone and the radiotelephone is location technology capable, the radiotelephone attempts to locate the particular private User Zone (505 or 506). This is accomplished by using the location information parameters of the User Zone that were transmitted by the serving base station.

If the radiotelephone locates the private system (505 or 506), it may start to acquire the private system by tuning to the frequency carrier of that private system and searching for the associated pilot. If the radiotelephone successfully finds the pilot, the alphanumeric tag of the User Zone supported by that private system is displayed on the radiotelephone's display and the radiotelephone registers with the private system (505 or 506). As in previously described embodiments, the alphanumeric tag is a description of the

User Zone such as "NORTEL" (505), "Al's Hardware Store" (506), or "Drug Store" (506). If the radiotelephone fails to acquire the located private system, it may stay in the current system and start the acquisition process again at a later time.

FIG. 6 illustrates a wireless communication system with private carrier, autonomous User Zones. This embodiment uses a location dependent search scheme.

The system of FIG. 6 illustrates two public systems (601 and 602). Public system 1 (601) operates on one frequency, f2, but is split into two sectors (605 and 606) that use different PN offsets, 10 (605) and 50 (606). The entire public system 1 (601) operates in band class B.

Public system 1 (601) overlays two private system (615 and 612). Private system 1 (615) operates on a separate frequency, f3, and is comprised of two base stations (610 and 611) that are assigned PN offsets: PN=20 and 100. Private system 2 (612) operates on the same frequency, f3, but with a PN offset of 200.

Public system 2 (602) operates on frequency f4 and is assigned PN offset 100. This system (602) overlays one private system (625) that operates on frequency f5 and is assigned PN offset 110.

In this embodiments all of the private systems (615, 612, and 625) have associated latitude and longitude coordinates with a radius of the private system's coverage. In alternate embodiments, other private system boundary specification parameters can be used.

As in the autonomous User Zones of FIG. 3, the serving base station of the overlaying public system does not broadcast the private system information of the embodiment of FIG. 6. The Private System List or preferred roaming list that is stored in the radiotelephone assists the radiotelephone in finding the autonomous private User Zones.

For location technology capable radiotelephones, the stored list includes the UZIDs and the associated location information parameters identifying the boundaries of the private systems of interest. These parameters are dependant on the location technology process supported (i.e., GPS, triangulation, or others).

The radiotelephone uses the location information to search for the User Zone of interest. Once the radiotelephone uses the location technology to determine that it is within the boundaries of the User Zone of interest, it tunes to the corresponding frequency and searches for the pilot channel. Once the pilot channel is found, the radiotelephone registers with that private system. In this embodiment, the alphanumeric tag for the private system may be displayed on the radiotelephone's display.

FIG. 7 illustrates a public carrier, virtual User Zone embodiment. The User Zones of this embodiment use the carrier and resources of the overlaying public system.

This embodiment is comprised of a public system (701) in which the serving base station broadcasts the User Zone information. This information includes the User Zone ID and the latitude, longitude, and radius of each particular User Zone ID. In alternate embodiments, other User Zone boundary specification parameters can be used.

In the embodiment of FIG. 7, two virtual User Zones (705 and 706) are provided. The latitude/longitude and radius that is broadcast by the serving base station identify the boundaries of these User Zones.

When the radiotelephone powers up or enters the coverage area of a public system base station, it obtains the supported User Zone IDs from the paging channel. If the radiotelephone finds a User Zone ID match with those stored in the radiotelephone, the radiotelephone attempts to locate the User Zone using the broadcast location information parameters.

These parameters, in an alternate embodiment, could have been stored in the radiotelephone's memory along with the User Zone ID. In this embodiment, the serving base station would only broadcast the User Zone IDs of the User Zones within its service area.

If the radiotelephone determines that it is within the boundaries of a particular User Zone (705 or 706), it displays the alphanumeric tag associated with that User Zone (705 or 706). The radiotelephone then registers with the User Zone (705 or 706).

In any of the previously discussed embodiments in which the radiotelephone stores User Zone IDs and information, the radiotelephone can acquire the User Zone IDs or information in multiple ways. These methods include over the air programming, and querying the system for information.

Over the air programming allows an operator to download User Zone ID lists and associated information to the radiotelephone's memory. The downloaded information may be stored permanently or only for a power cycle.

The radiotelephone can also query the system for information about possible service in a User Zone that has been broadcast by the serving base station. These User Zones are not listed in the radiotelephone's memory. In response to the query, the base station identifies the User Zones that are accepting radiotelephone registration and sends all the associated information (UZID, alpha tags, lat./long./radius). The radiotelephone then retains the UZIDs and information in its memory, either through a power cycle or permanently.

FIG. 2 illustrates the private system selection process of the present invention. The process starts by the radiotelephone powering up and monitoring the public system (step 201). The radiotelephone then obtains the private system/User Zone identification information from the broadcast channel or other channel used to disseminate this information (step 205).

The radiotelephone accesses the system information from the Private System List in memory (step 210). The radiotelephone then attempts to determine if a private system/User Zone, not programmed into memory, is available using the Private System List information (step 215). Depending on the embodiment, the radiotelephone uses either location based technology to determine the local private systems and then performs a search for pilot signals or performs a search for all pilot signals retrieved from memory.

If a system is found, the radiotelephone requests system information from all of the private systems/User Zones (step 220) that were discovered. The radiotelephone then obtains the private system/User Zone information of systems that will accept registration by the radiotelephone (step 225).

If no non-programmed private systems/User Zones are found (step 215), the alphanumeric tags for each system that is available are displayed for the user to choose (step 230) the system/User Zone in which they wish to register. The user can then scroll through the list to select the desired User Zone. Once the user has selected the desired system, the radiotelephone attempts to locate that system (step 235).

If the radiotelephone is not successful in locating the selected system (step 235), the radiotelephone registers with the public system (step 250).

If the selected system is located (step 235), the system information is displayed to allow the user to decide whether

to register with that system (step **240**). If selected, the radiotelephone then registers with that system (step **245**).

In one embodiment of the present invention, the private systems store tables of mobile identification numbers for radiotelephones to which the systems will allow access. These tables can be stored at the base station or other locations within the private system. The private systems, in an alternate embodiment, store tables of mobile identification numbers for radiotelephones to which the systems will not allow access.

FIG. **8** illustrates a block diagram of the radiotelephone that operates in the wireless communication systems of the present invention. The radiotelephone is comprised of a controller (**815**) for controlling the radiotelephone. Memory (**810**) is used to store the radiotelephone information as well as the public and private system information. A transceiver (**801**) transmits modulated (**805**) information over the channel and receives information from the channel to be demodulated (**805**). The antenna (**800**) radiates and receives the radiotelephone signals.

In summary, the CDMA based systems of the present invention provide a complete solution for supporting private, semi-private, and residential systems without interfering with the overlaying public system. By creating private User Zone systems that underlay a public system, a set of features and services can be offered to subscribers that have subscribed to the User Zones. This is accomplished without interfering with the overlaying public system.

We claim:

1. A method for radiotelephone operation in a wireless communications system using CDMA air interface, the wireless communications system comprising a public system and a plurality of underlaid private systems, the radiotelephone having a display and memory that stores private systems information, the method comprising the steps of:

the public system broadcasting private systems information on a predetermined paging channel;

the radiotelephone monitoring the predetermined paging channel; and

the radiotelephone locating and acquiring a subset of private systems of the plurality of underlaid private systems in response to the broadcast private systems information and the stored private systems information by:

matching broadcast user zone identifications supported by the plurality of underlaid private systems to stored user zone identifications in the radiotelephone;

if a single stored user zone identification is matched, attempting to access a corresponding private system of the plurality of underlaid private systems;

if multiple stored user zone identifications are matched, using a predetermined priority list to select and attempt access a corresponding private system of the plurality of underlaid private systems; and

if an initial access of the corresponding private system is not successful, attempting to access another private system supporting the user zone identification.

2. A method for radiotelephone operation in a wireless communication system using CDMA air interface, the wireless communication system including a public system and a plurality of underlaid private systems, the radiotelephone having a display and memory, the method comprising:

receiving broadcast information from the public system;

attempting to retrieve private system/user zone information from the broadcast information;

if the broadcast information includes private system/user zone, storing the private system/user zone information in memory;

attempting to retrieve additional private system/user zone information from memory;

compiling all retrieved private system/user zone information;

determining at least one private system of the plurality of underlaid private systems to access based upon the all retrieved private system/user zone information by matching broadcast user zone identifications supported by the plurality of underlaid private systems to user zone identifications stored in the radiotelephone;

if a single stored user zone identification is matched, selecting and attempting to access a corresponding first private system of the plurality of underlaid private systems;

if multiple stored user zone identifications are matched, using a predetermined priority list to select, and attempt to access a corresponding first private system of the plurality of underlaid private systems; and

if an initial access of the first private system is not successful, selecting and attempting to access a second private system corresponding to a matched user zone identification.

3. The method of claim **2**, further comprising if attempting to register with the first private system is unsuccessful, attempting to register with the public system.

4. The method of claim **2**, further comprising:

displaying at least one matched user zone identification to a user of the radiotelephone on the display;

receiving instructions from the user regarding private system selection; and

based upon the instructions from the user, determining the first private system.

5. The method of claim **2**, wherein the broadcast information from the public system does not include user zone identifications.

6. The method of claim **2**, wherein:

the public system and the plurality of underlaid private systems share a common carrier frequency; and

each of the public system and the plurality of underlaid private systems has a unique respective pseudo-noise offset.

7. The method of claim **2**, wherein:

the public system operates on a first carrier frequency;

the plurality of underlaid private systems operate on a second carrier frequency; and

each of the plurality of underlaid private systems has a unique respective pseudo-noise offset.

8. The method of claim **2**, wherein each of the plurality of underlaid private systems corresponds to a respective premises.

9. A radiotelephone that operates in a wireless communication system using CDMA air interface, the wireless communication system including a public system and a plurality of underlaid private systems, the radiotelephone having a display and memory, the radio telephone comprising:

means for receiving broadcast information from the public system;

means for attempting to retrieve private system/user zone information from the broadcast information;

means for, if the broadcast information includes private system/user zone, storing the private system/user zone information in memory;

means for attempting to retrieve additional private system/user zone information from memory;

means for compiling all retrieved private system/user zone information;

means for determining at least one private system of the plurality of underlaid private systems to access based upon the all retrieved private system/user zone information by matching broadcast user zone identifications supported by the plurality of underlaid private systems to user zone identifications stored in the radiotelephone;

means for, if a single stored user zone identification is matched, selecting and attempting to access a corresponding first private system of the plurality of underlaid private systems;

means for, if multiple stored user zone identifications are matched, using a predetermined priority list to select, and attempt to access a corresponding first private system of the plurality of underlaid private systems; and

means for, if an initial access of the first private system is not successful, selecting and attempting to access a second private system corresponding to a matched user zone identification.

10. The radiotelephone of claim **9**, further comprising:

means for, if attempting to register with the first private system is unsuccessful, attempting to register with the public system.

11. The radiotelephone of claim **9**, further comprising:

means for displaying at least one matched user zone identification to a user of the radiotelephone on the display;

means for receiving instructions from the user regarding private system selection; and

means for, based upon the instructions from the user, determining the first private system.

12. The radiotelephone of claim **9**, wherein the broadcast information from the public system does not include user zone identifications.

13. The radiotelephone of claim **9**, wherein:

the public system and the plurality of underlaid private systems share a common carrier frequency; and

each of the public system and the plurality of underlaid private systems has a unique respective pseudo-noise offset.

14. The radiotelephone of claim **9**, wherein:

the public system operates on a first carrier frequency;

the plurality of underlaid private systems operate on a second carrier frequency; and

each of the plurality of underlaid private systems has a unique respective pseudo-noise offset.

15. The radiotelephone of claim **9**, wherein each of the plurality of underlaid private systems corresponds to a respective premises.

* * * * *

US006701132B1

(12) United States Patent
Fukuzawa et al.

(10) Patent No.: US 6,701,132 B1
(45) Date of Patent: Mar. 2, 2004

(54) MOBILE COMMUNICATION SYSTEM, MOBILE STATION, AND BASE STATION THAT CALCULATES DISTANCE FROM MOBILE STATION

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(73) Assignee: **Hitachi, Ltd.** (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/517,483**

(22) Filed: **Mar. 2, 2000**

(30) **Foreign Application Priority Data**

Jul. 30, 1999 (JP) 11-217912

(51) **Int. Cl.**[7] **H04B 17/00**
(52) **U.S. Cl.** **455/67.6**; 455/561
(58) **Field of Search** 455/403, 422, 455/434, 450, 453, 11.1, 509, 67.6, 550, 560, 561, 242.1, 243.1, 456; 370/508, 519

(56) **References Cited**

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JP	10322752	12/1998	.... H04Q/7/34

* cited by examiner

Primary Examiner—Thanh Cong Le
Assistant Examiner—Tu Nguyen
(74) *Attorney, Agent, or Firm*—Sofer & Haroun, LLP

(57) **ABSTRACT**

A mobile communication system that can obtain mobile station location information repeatedly at short intervals, without depending on whether base stations are synchronous or asynchronous, with lower loads and suppressed use of radio resources. For obtaining location information, a mobile station receives a paging channel periodically sent from a base station (Step **100**), obtains the contents and the reception timing of this paging channel. Further, if it is necessary to obtain the transmission timing of the paging channel, that transmission timing is obtained (Steps **105**, **106**). The propagation delay of the paging channel or propagation delay differences between a plurality of periodic paging channels are calculated from the transmission timing and the reception timing of the paging channel (Step **107**). The mobile station location information is calculated from the propagation delay or propagation delay difference, and outputted (Steps **108**, **109**, **110**).

9 Claims, 19 Drawing Sheets

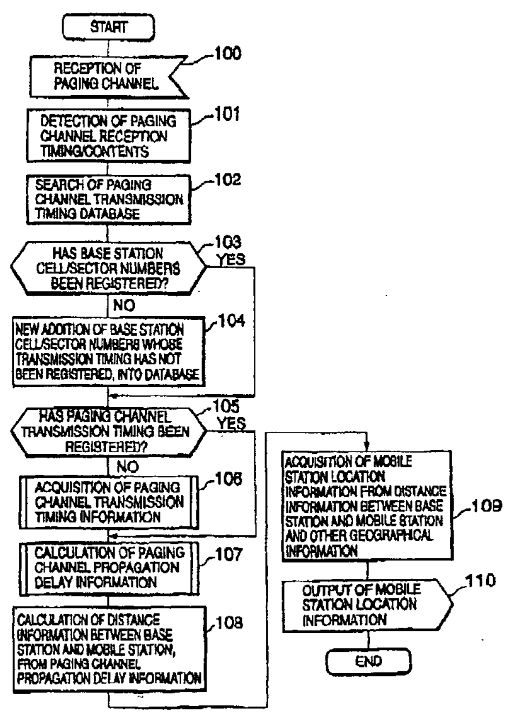


FIG. 1

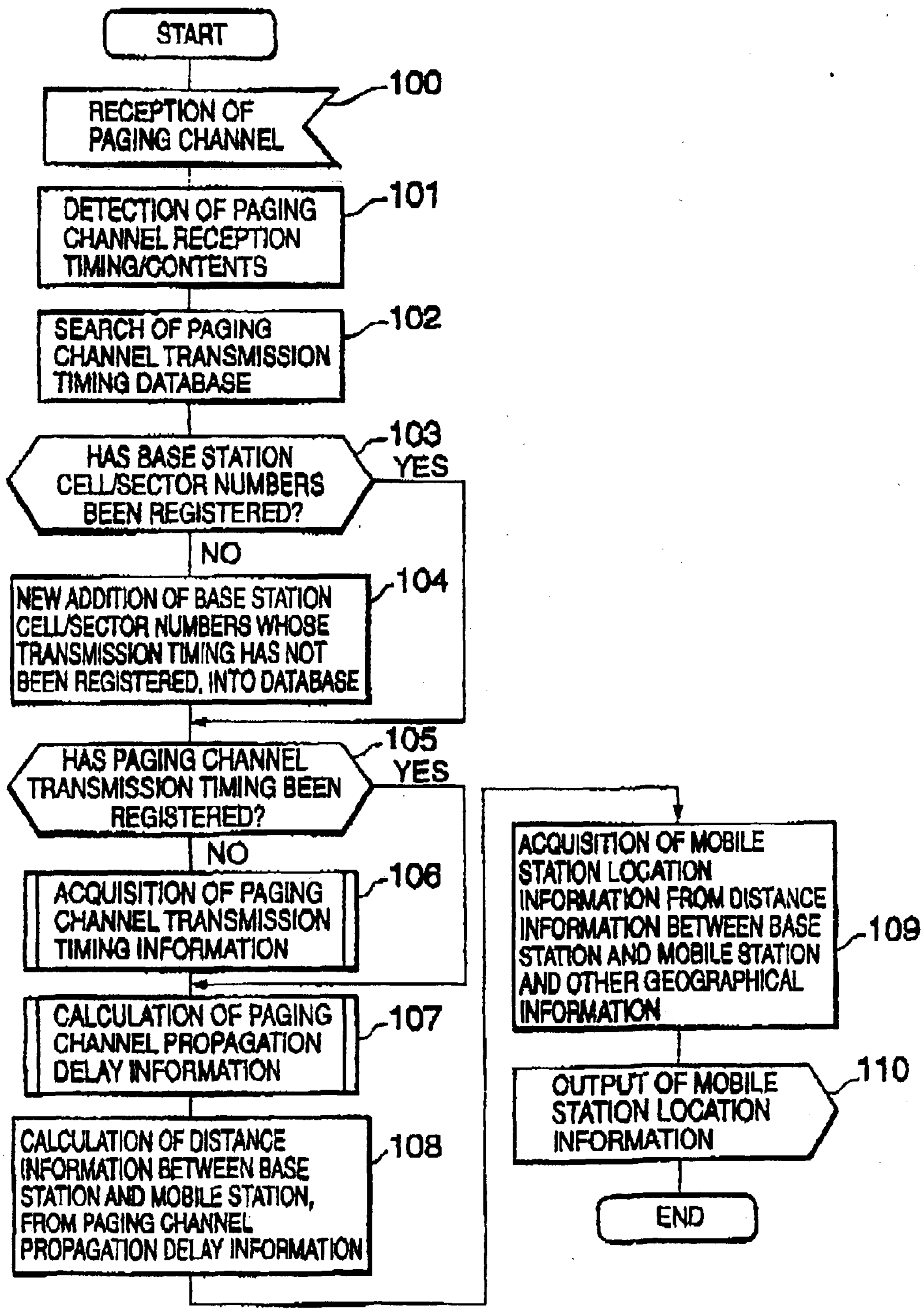

START
RECEPTION OF PAGING CHANNEL
100
DETECTION OF PAGING CHANNEL RECEPTION TIMING/CONTENTS
101
SEARCH OF PAGING CHANNEL TRANSMISSION TIMING DATABASE
102
HAS BASE STATION CELL/SECTOR NUMBERS BEEN REGISTERED?
103
YES
NO
NEW ADDITION OF BASE STATION CELL/SECTOR NUMBERS WHOSE TRANSMISSION TIMING HAS NOT BEEN REGISTERED, INTO DATABASE
104
HAS PAGING CHANNEL TRANSMISSION TIMING BEEN REGISTERED?
105
YES
NO
ACQUISITION OF PAGING CHANNEL TRANSMISSION TIMING INFORMATION
106
CALCULATION OF PAGING CHANNEL PROPAGATION DELAY INFORMATION
107
CALCULATION OF DISTANCE INFORMATION BETWEEN BASE STATION AND MOBILE STATION, FROM PAGING CHANNEL PROPAGATION DELAY INFORMATION
108
ACQUISITION OF MOBILE STATION LOCATION INFORMATION FROM DISTANCE INFORMATION BETWEEN BASE STATION AND MOBILE STATION AND OTHER GEOGRAPHICAL INFORMATION
109
OUTPUT OF MOBILE STATION LOCATION INFORMATION
110
END

FIG. 2

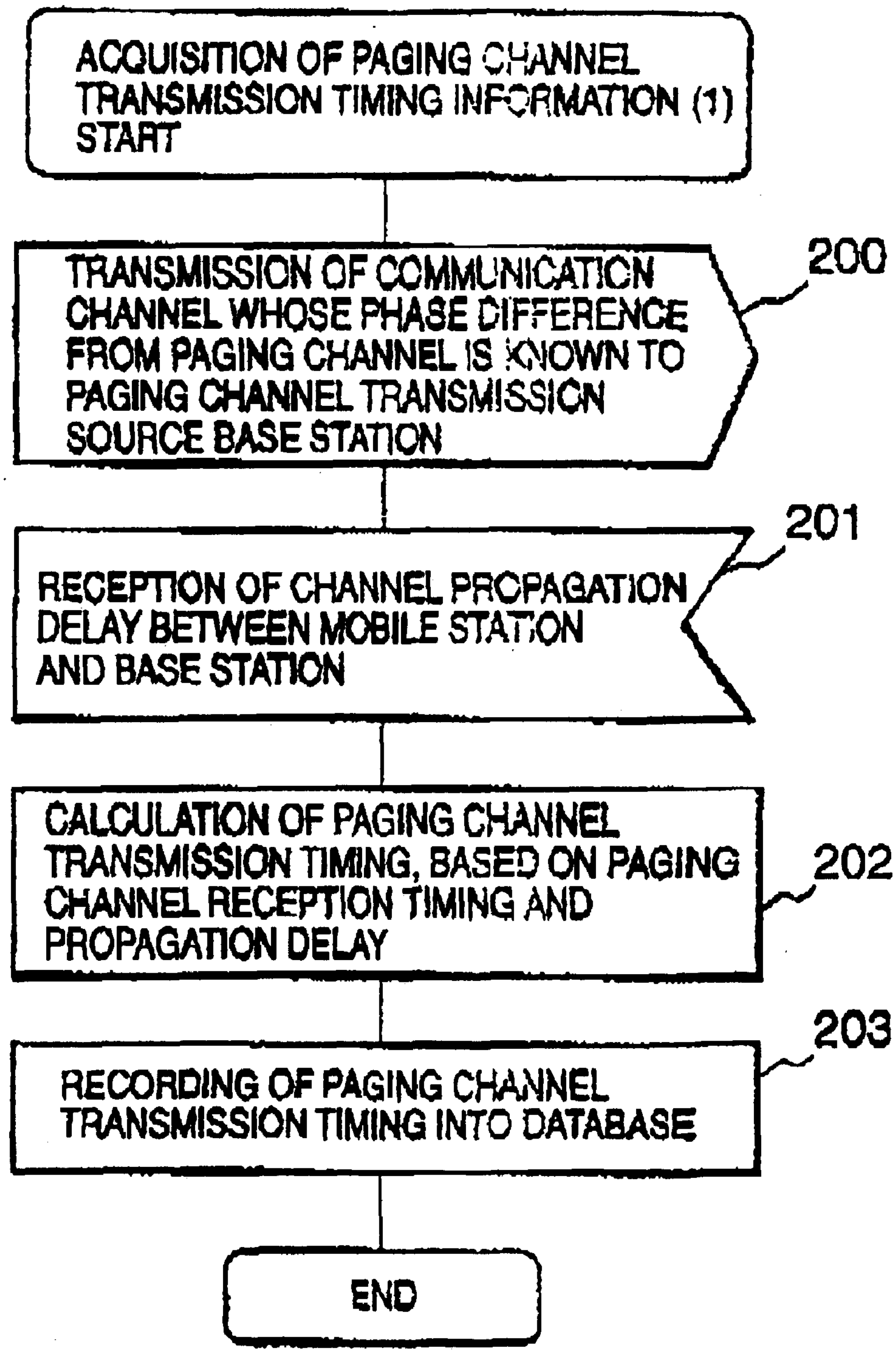

ACQUISITION OF PAGING CHANNEL TRANSMISSION TIMING INFORMATION (1) START
TRANSMISSION OF COMMUNICATION CHANNEL WHOSE PHASE DIFFERENCE FROM PAGING CHANNEL IS KNOWN TO PAGING CHANNEL TRANSMISSION SOURCE BASE STATION
200
RECEPTION OF CHANNEL PROPAGATION DELAY BETWEEN MOBILE STATION AND BASE STATION
201
CALCULATION OF PAGING CHANNEL TRANSMISSION TIMING, BASED ON PAGING CHANNEL RECEPTION TIMING AND PROPAGATION DELAY
202
RECORDING OF PAGING CHANNEL TRANSMISSION TIMING INTO DATABASE
203
END

FIG. 3

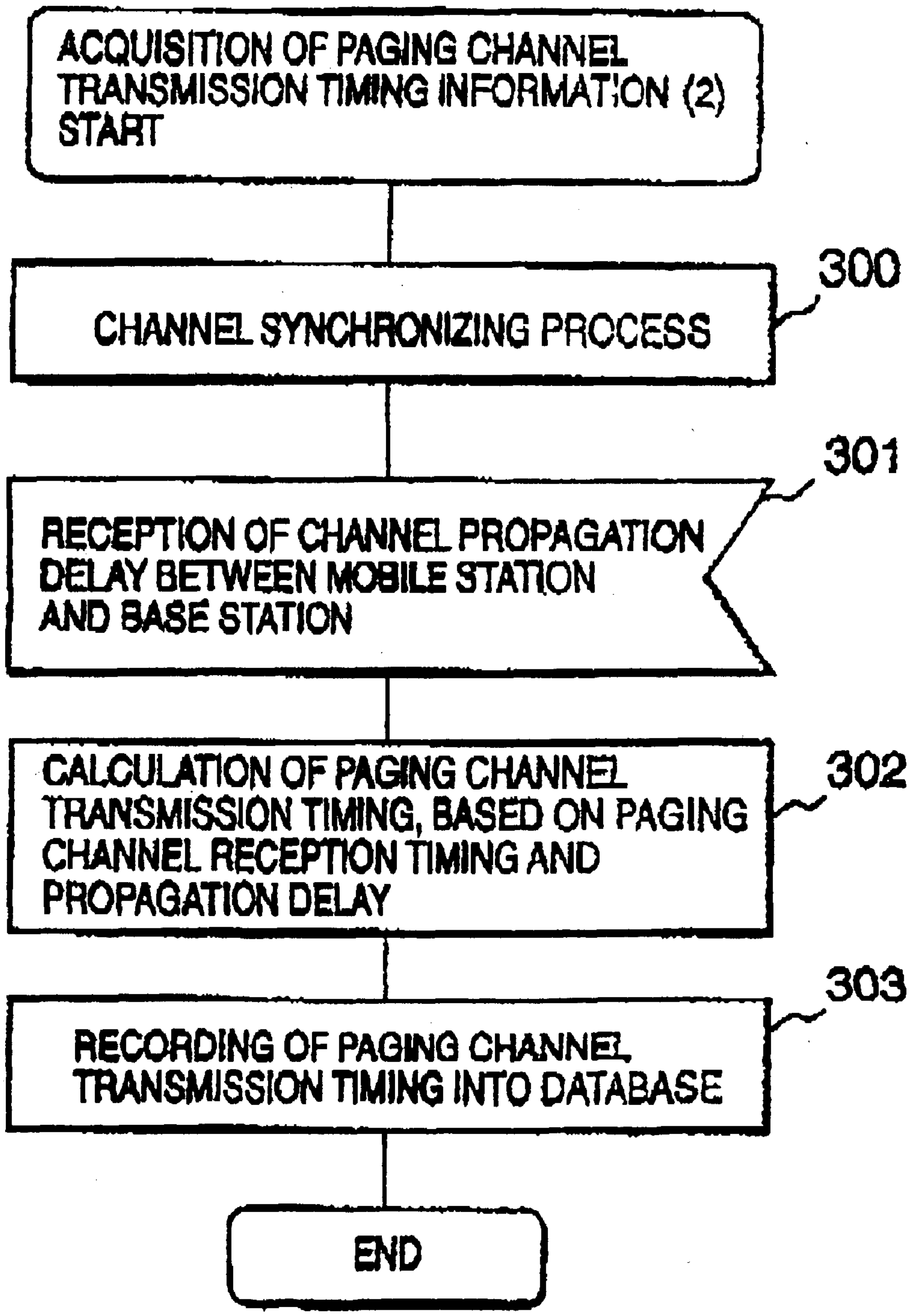

ACQUISITION OF PAGING CHANNEL TRANSMISSION TIMING INFORMATION (2) START
CHANNEL SYNCHRONIZING PROCESS
300
RECEPTION OF CHANNEL PROPAGATION DELAY BETWEEN MOBILE STATION AND BASE STATION
301
CALCULATION OF PAGING CHANNEL TRANSMISSION TIMING, BASED ON PAGING CHANNEL RECEPTION TIMING AND PROPAGATION DELAY
302
RECORDING OF PAGING CHANNEL TRANSMISSION TIMING INTO DATABASE
303
END

FIG. 4

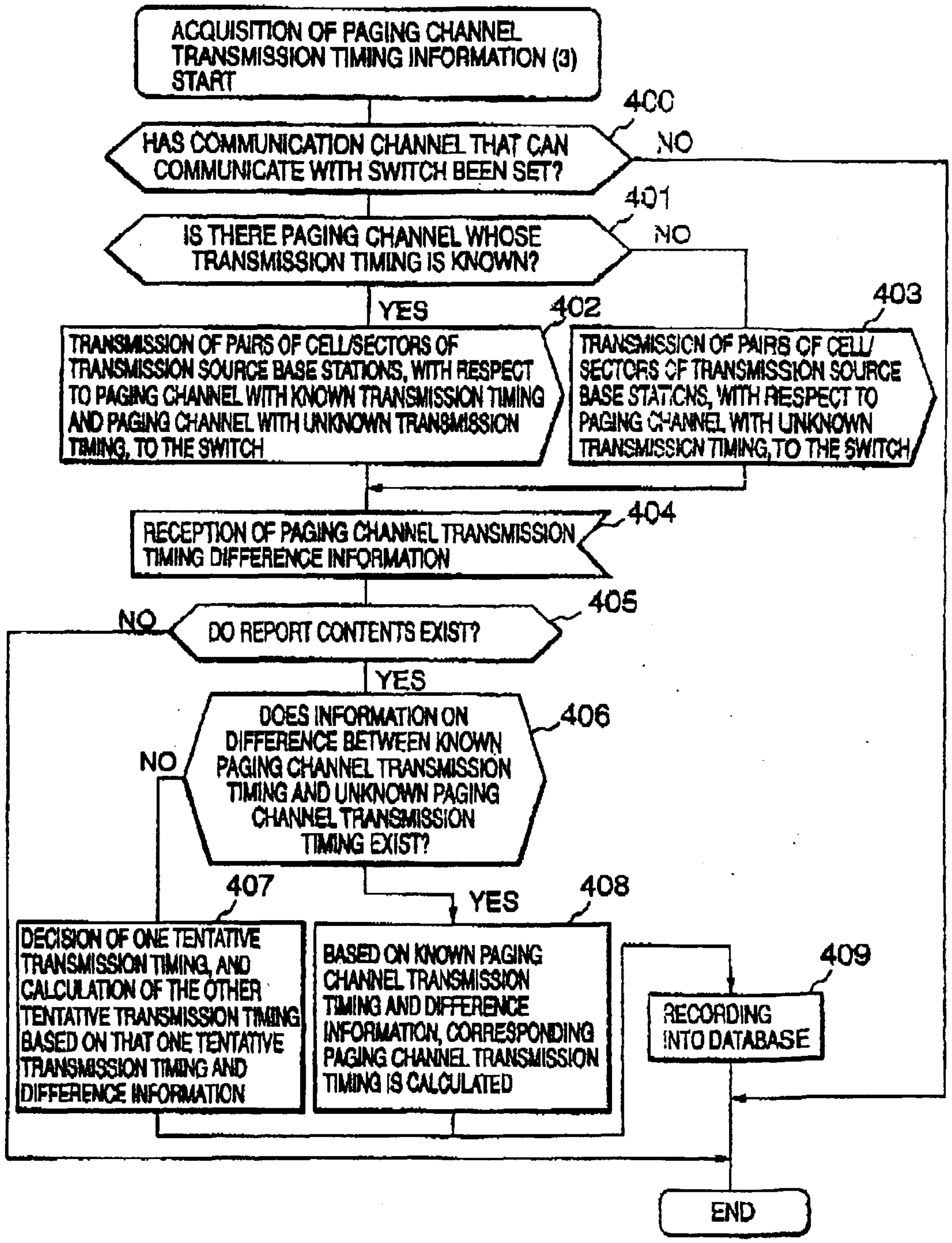

ACQUISITION OF PAGING CHANNEL TRANSMISSION TIMING INFORMATION (3) START
400
HAS COMMUNICATION CHANNEL THAT CAN COMMUNICATE WITH SWITCH BEEN SET?
NO
401
IS THERE PAGING CHANNEL WHOSE TRANSMISSION TIMING IS KNOWN?
NO
YES
402
TRANSMISSION OF PAIRS OF CELL/SECTORS OF TRANSMISSION SOURCE BASE STATIONS, WITH RESPECT TO PAGING CHANNEL WITH KNOWN TRANSMISSION TIMING AND PAGING CHANNEL WITH UNKNOWN TRANSMISSION TIMING, TO THE SWITCH
403
TRANSMISSION OF PAIRS OF CELL/SECTORS OF TRANSMISSION SOURCE BASE STATIONS, WITH RESPECT TO PAGING CHANNEL WITH UNKNOWN TRANSMISSION TIMING, TO THE SWITCH
404
RECEPTION OF PAGING CHANNEL TRANSMISSION TIMING DIFFERENCE INFORMATION
405
NO
DO REPORT CONTENTS EXIST?
YES
406
DOES INFORMATION ON DIFFERENCE BETWEEN KNOWN PAGING CHANNEL TRANSMISSION TIMING AND UNKNOWN PAGING CHANNEL TRANSMISSION TIMING EXIST?
NO
YES
407
DECISION OF ONE TENTATIVE TRANSMISSION TIMING, AND CALCULATION OF THE OTHER TENTATIVE TRANSMISSION TIMING BASED ON THAT ONE TENTATIVE TRANSMISSION TIMING AND DIFFERENCE INFORMATION
408
BASED ON KNOWN PAGING CHANNEL TRANSMISSION TIMING AND DIFFERENCE INFORMATION, CORRESPONDING PAGING CHANNEL TRANSMISSION TIMING IS CALCULATED
409
RECORDING INTO DATABASE
END

FIG. 5

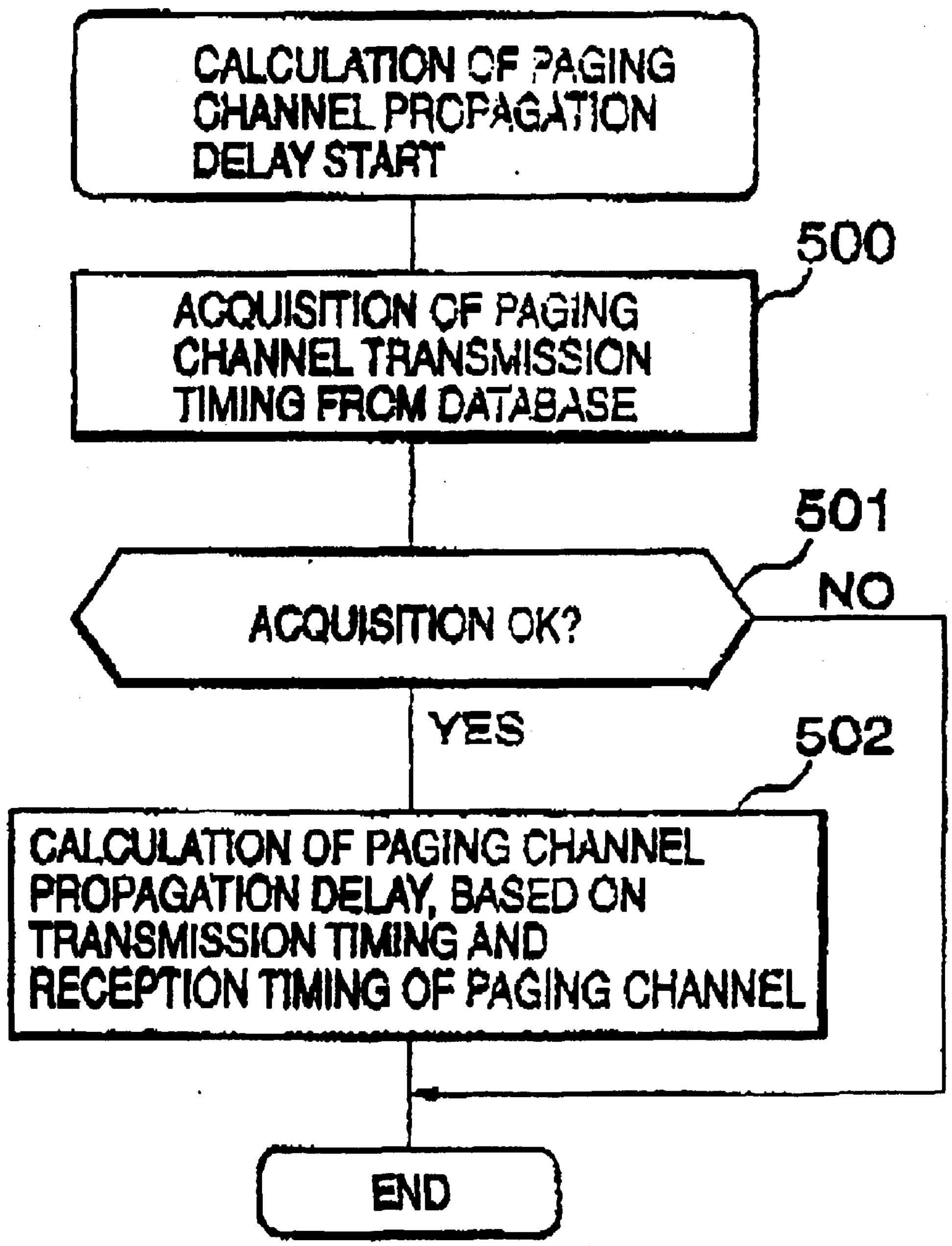

CALCULATION OF PAGING CHANNEL PROPAGATION DELAY START
500
ACQUISITION OF PAGING CHANNEL TRANSMISSION TIMING FROM DATABASE
501
ACQUISITION OK?
NO
YES
502
CALCULATION OF PAGING CHANNEL PROPAGATION DELAY, BASED ON TRANSMISSION TIMING AND RECEPTION TIMING OF PAGING CHANNEL
END

FIG. 6

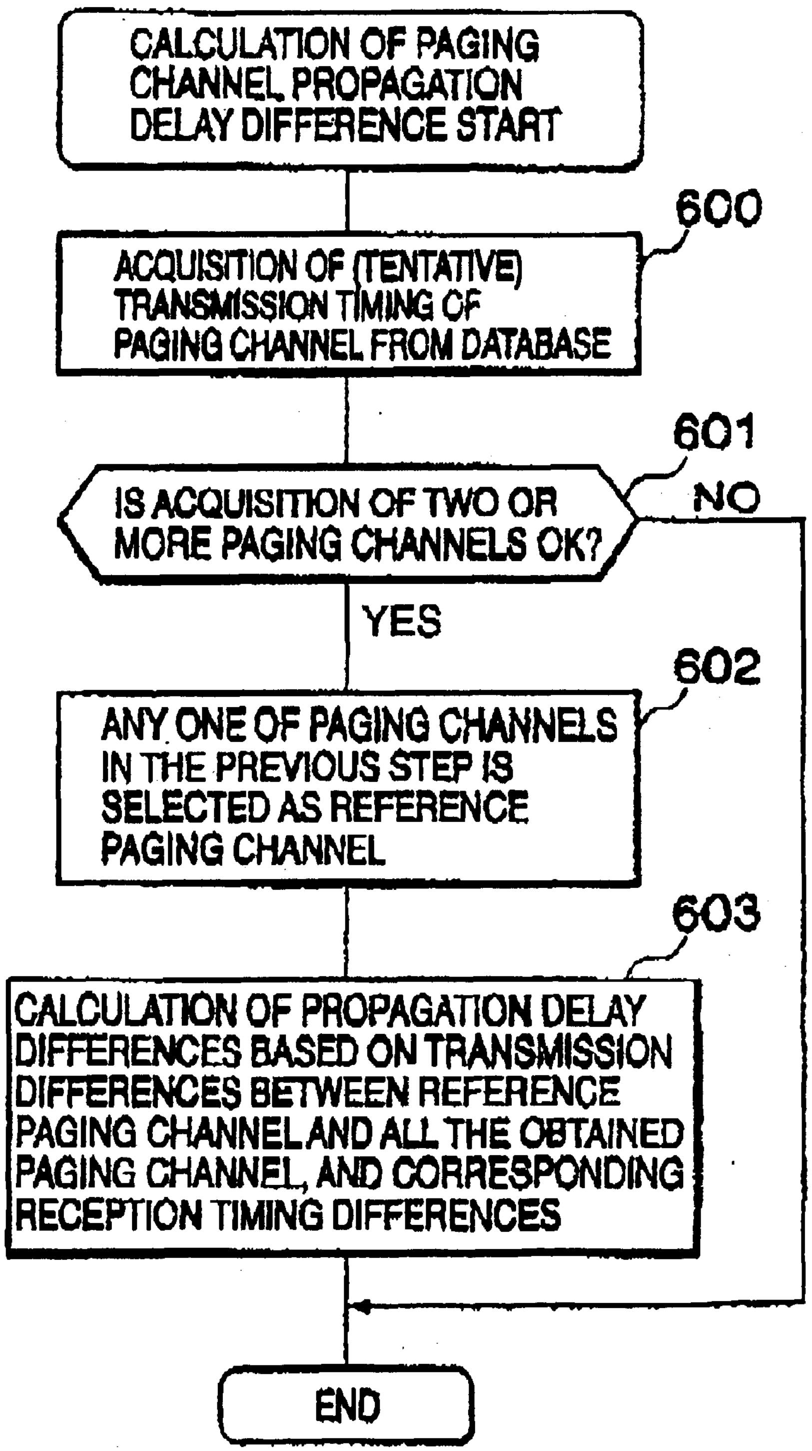

CALCULATION OF PAGING CHANNEL PROPAGATION DELAY DIFFERENCE START
600
ACQUISITION OF (TENTATIVE) TRANSMISSION TIMING OF PAGING CHANNEL FROM DATABASE
601
IS ACQUISITION OF TWO OR MORE PAGING CHANNELS OK?
NO
YES
602
ANY ONE OF PAGING CHANNELS IN THE PREVIOUS STEP IS SELECTED AS REFERENCE PAGING CHANNEL
603
CALCULATION OF PROPAGATION DELAY DIFFERENCES BASED ON TRANSMISSION DIFFERENCES BETWEEN REFERENCE PAGING CHANNEL AND ALL THE OBTAINED PAGING CHANNEL, AND CORRESPONDING RECEPTION TIMING DIFFERENCES
END

FIG. 7

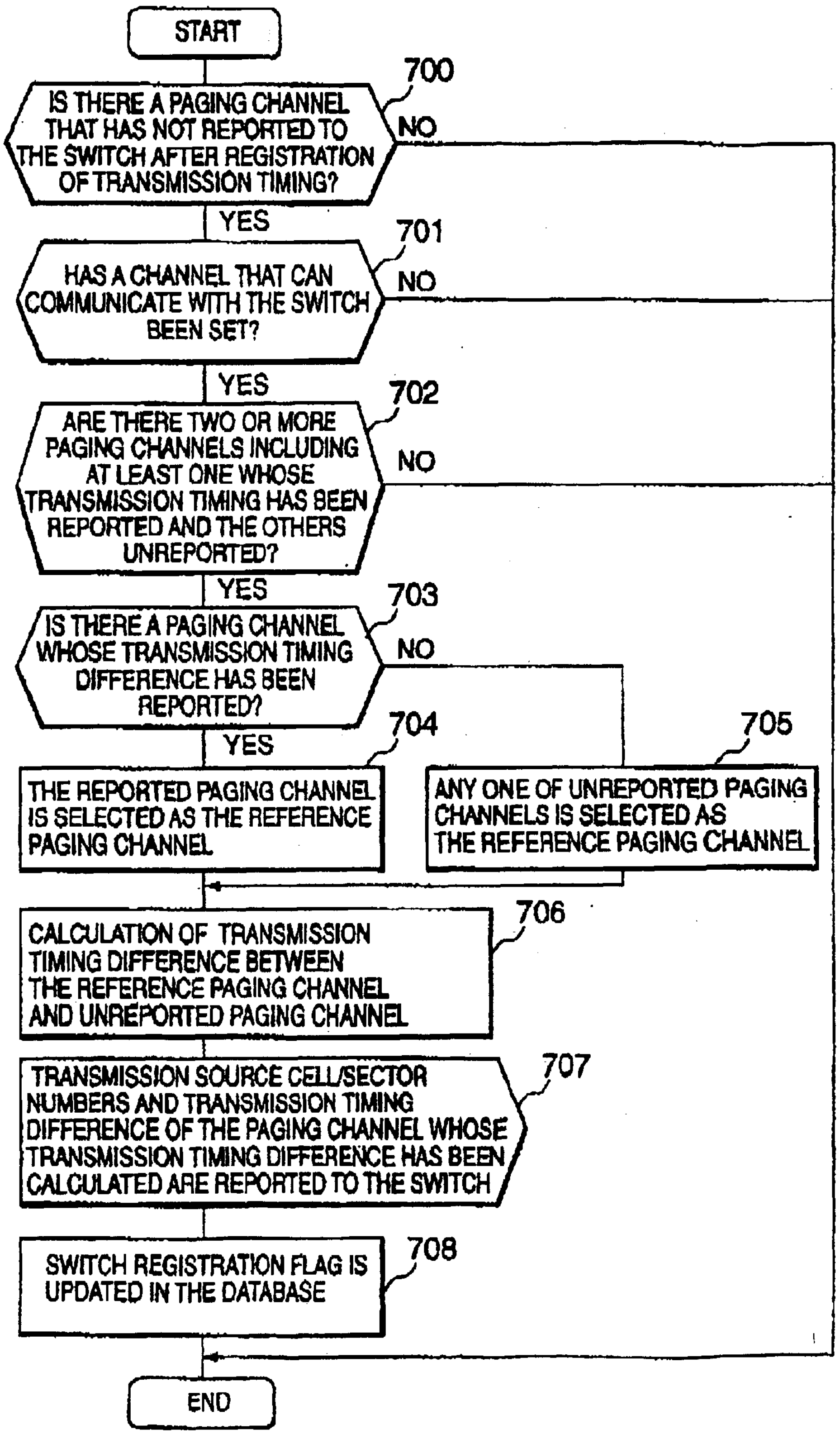

START
700
IS THERE A PAGING CHANNEL THAT HAS NOT REPORTED TO THE SWITCH AFTER REGISTRATION OF TRANSMISSION TIMING?
NO
YES
701
HAS A CHANNEL THAT CAN COMMUNICATE WITH THE SWITCH BEEN SET?
NO
YES
702
ARE THERE TWO OR MORE PAGING CHANNELS INCLUDING AT LEAST ONE WHOSE TRANSMISSION TIMING HAS BEEN REPORTED AND THE OTHERS UNREPORTED?
NO
YES
703
IS THERE A PAGING CHANNEL WHOSE TRANSMISSION TIMING DIFFERENCE HAS BEEN REPORTED?
NO
YES
704
THE REPORTED PAGING CHANNEL IS SELECTED AS THE REFERENCE PAGING CHANNEL
705
ANY ONE OF UNREPORTED PAGING CHANNELS IS SELECTED AS THE REFERENCE PAGING CHANNEL
706
CALCULATION OF TRANSMISSION TIMING DIFFERENCE BETWEEN THE REFERENCE PAGING CHANNEL AND UNREPORTED PAGING CHANNEL
707
TRANSMISSION SOURCE CELL/SECTOR NUMBERS AND TRANSMISSION TIMING DIFFERENCE OF THE PAGING CHANNEL WHOSE TRANSMISSION TIMING DIFFERENCE HAS BEEN CALCULATED ARE REPORTED TO THE SWITCH
708
SWITCH REGISTRATION FLAG IS UPDATED IN THE DATABASE
END

FIG. 8

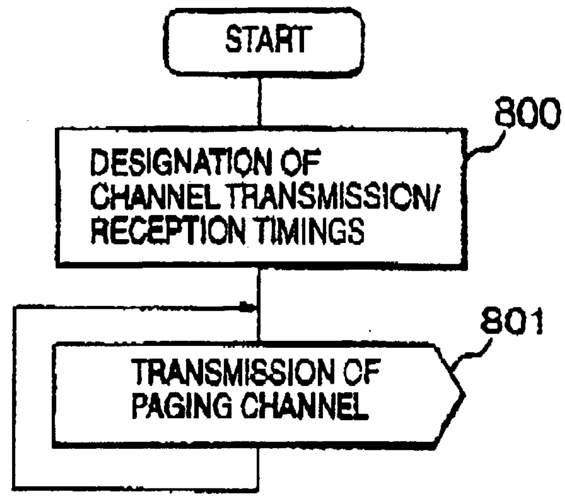

START
800
DESIGNATION OF CHANNEL TRANSMISSION/ RECEPTION TIMINGS
801
TRANSMISSION OF PAGING CHANNEL

FIG. 9

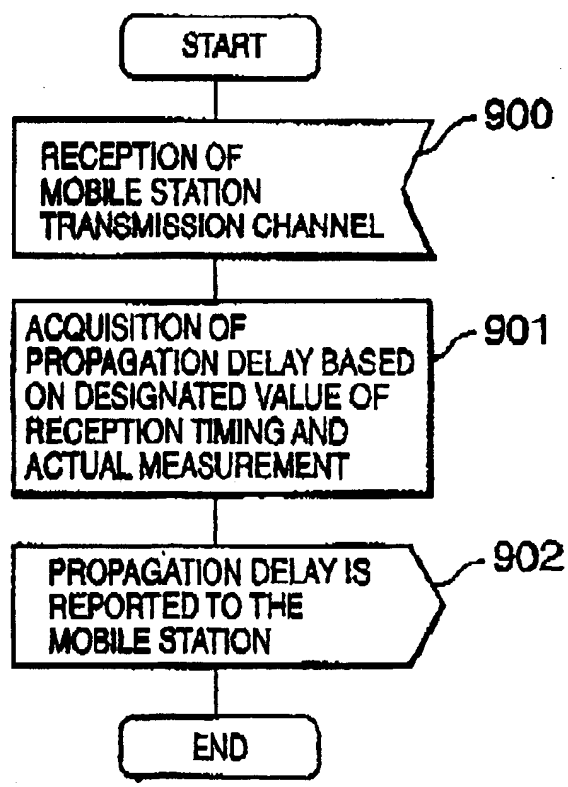

START
900
RECEPTION OF MOBILE STATION TRANSMISSION CHANNEL
901
ACQUISITION OF PROPAGATION DELAY BASED ON DESIGNATED VALUE OF RECEPTION TIMING AND ACTUAL MEASUREMENT
902
PROPAGATION DELAY IS REPORTED TO THE MOBILE STATION
END

FIG. 10

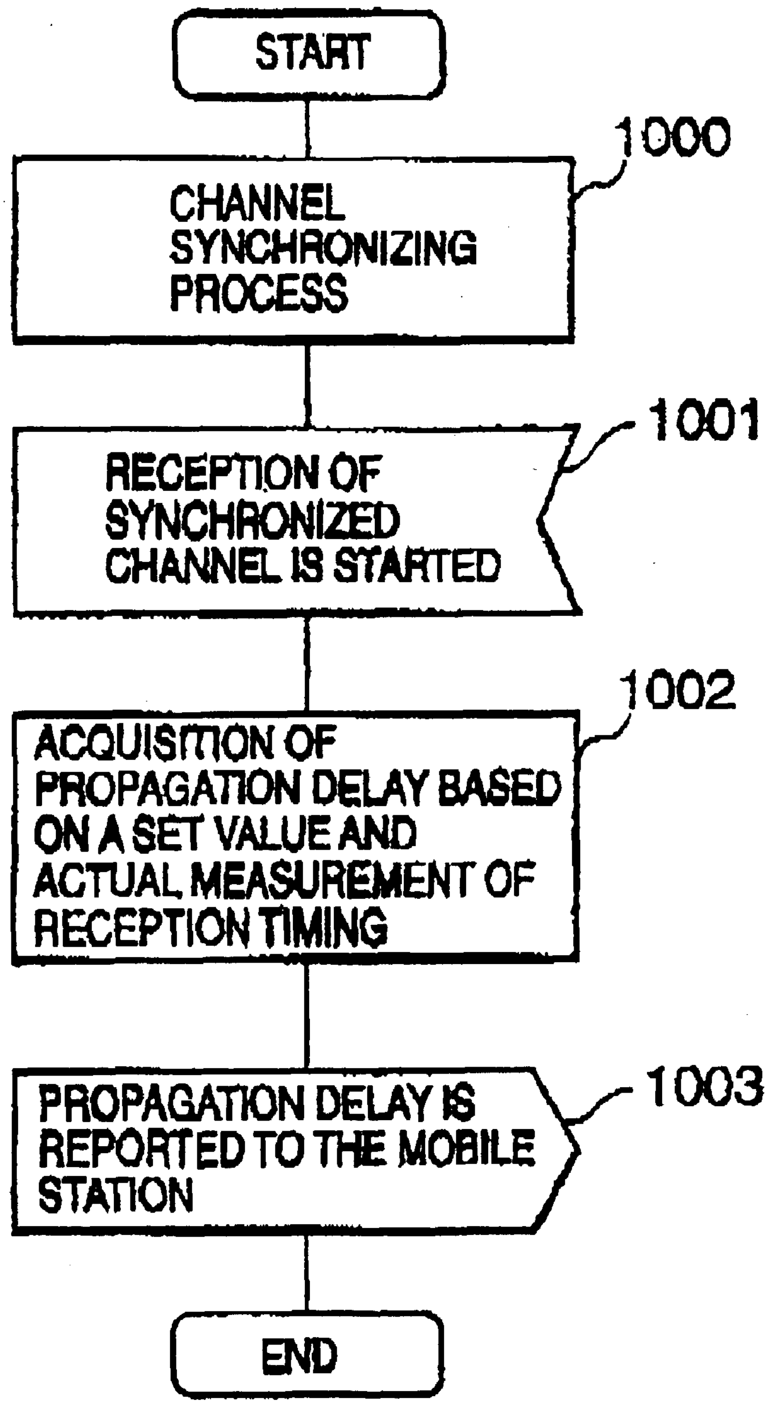

START
1000
CHANNEL SYNCHRONIZING PROCESS
1001
RECEPTION OF SYNCHRONIZED CHANNEL IS STARTED
1002
ACQUISITION OF PROPAGATION DELAY BASED ON A SET VALUE AND ACTUAL MEASUREMENT OF RECEPTION TIMING
1003
PROPAGATION DELAY IS REPORTED TO THE MOBILE STATION
END

FIG. 11

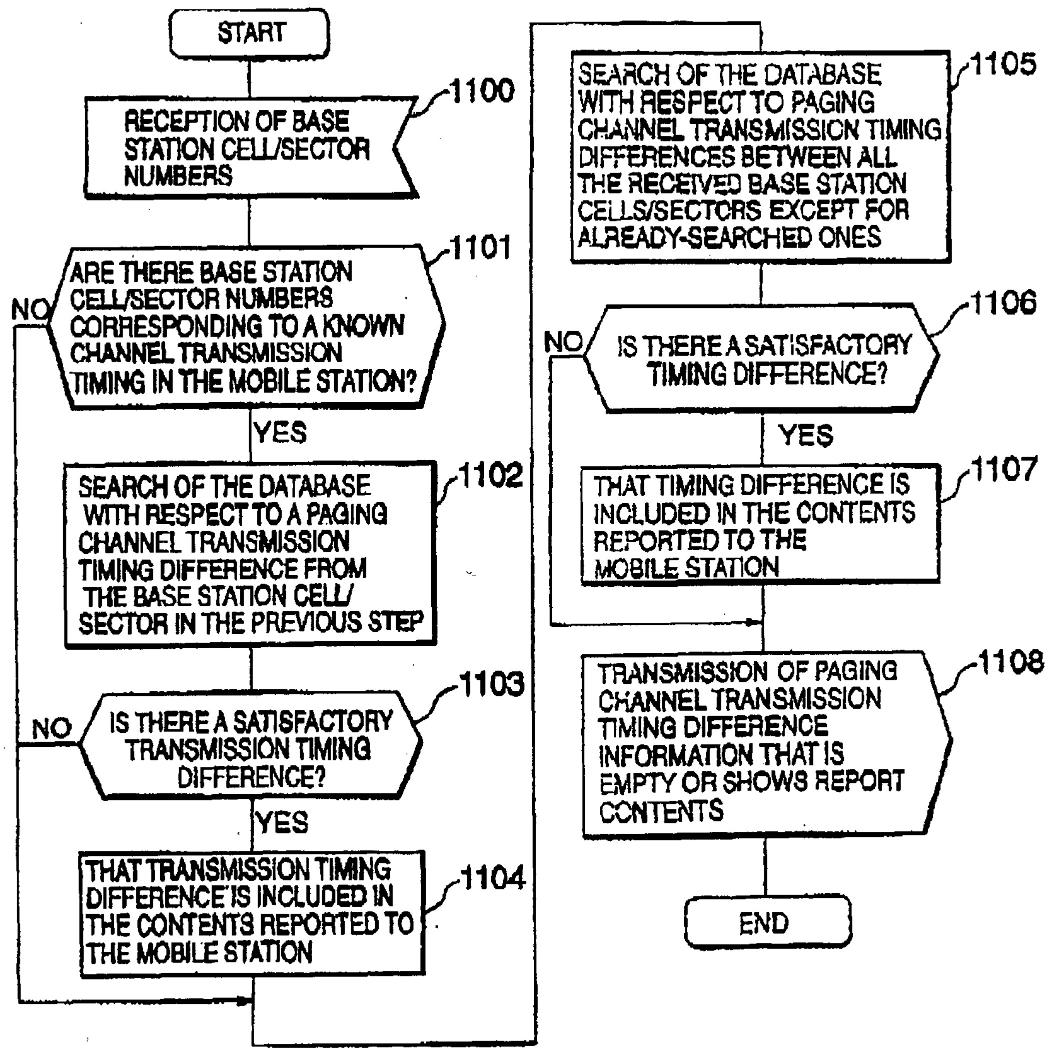

START
RECEPTION OF BASE STATION CELL/SECTOR NUMBERS
1100
ARE THERE BASE STATION CELL/SECTOR NUMBERS CORRESPONDING TO A KNOWN CHANNEL TRANSMISSION TIMING IN THE MOBILE STATION?
1101
NO
YES
SEARCH OF THE DATABASE WITH RESPECT TO A PAGING CHANNEL TRANSMISSION TIMING DIFFERENCE FROM THE BASE STATION CELL/ SECTOR IN THE PREVIOUS STEP
1102
IS THERE A SATISFACTORY TRANSMISSION TIMING DIFFERENCE?
1103
NO
YES
THAT TRANSMISSION TIMING DIFFERENCE IS INCLUDED IN THE CONTENTS REPORTED TO THE MOBILE STATION
1104
SEARCH OF THE DATABASE WITH RESPECT TO PAGING CHANNEL TRANSMISSION TIMING DIFFERENCES BETWEEN ALL THE RECEIVED BASE STATION CELLS/SECTORS EXCEPT FOR ALREADY-SEARCHED ONES
1105
IS THERE A SATISFACTORY TIMING DIFFERENCE?
1106
NO
YES
THAT TIMING DIFFERENCE IS INCLUDED IN THE CONTENTS REPORTED TO THE MOBILE STATION
1107
TRANSMISSION OF PAGING CHANNEL TRANSMISSION TIMING DIFFERENCE INFORMATION THAT IS EMPTY OR SHOWS REPORT CONTENTS
1108
END

FIG. 12

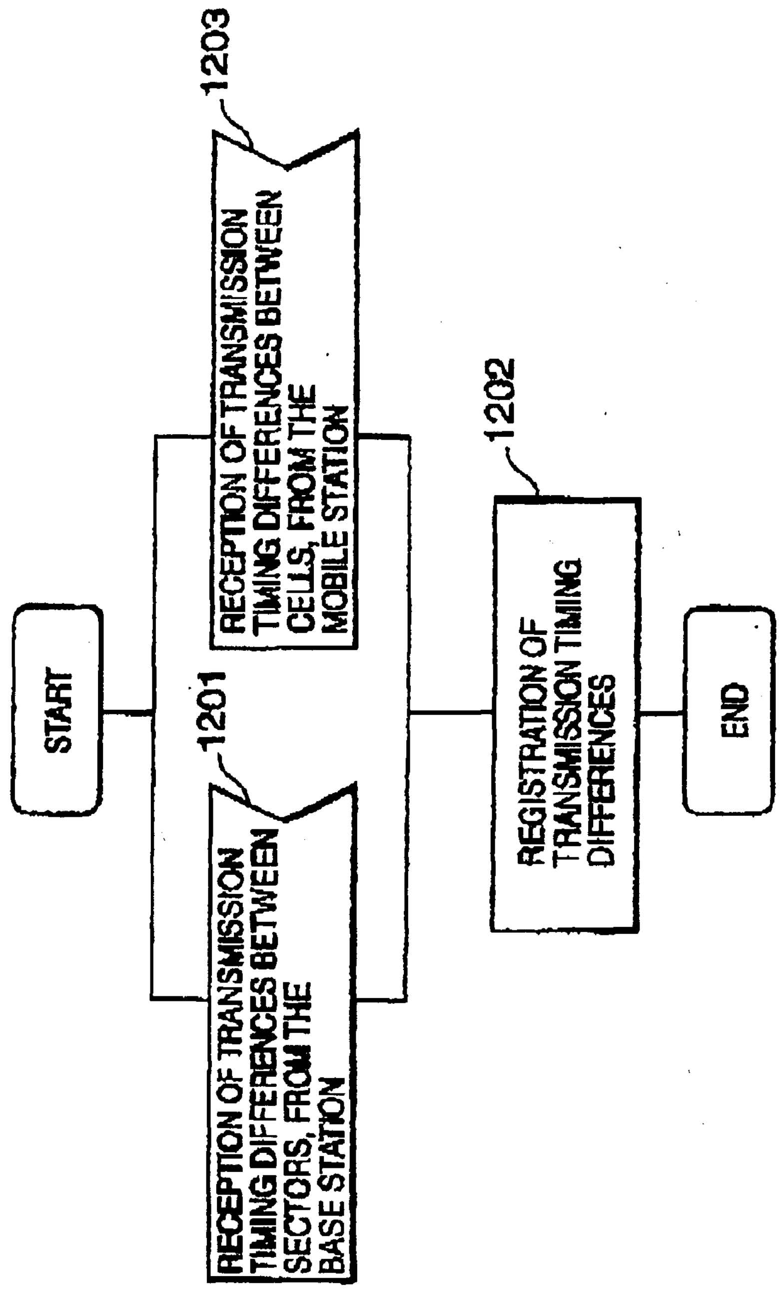

START
1201
RECEPTION OF TRANSMISSION TIMING DIFFERENCES BETWEEN SECTORS, FROM THE BASE STATION
1203
RECEPTION OF TRANSMISSION TIMING DIFFERENCES BETWEEN CELLS, FROM THE MOBILE STATION
1202
REGISTRATION OF TRANSMISSION TIMING DIFFERENCES
END

FIG. 13

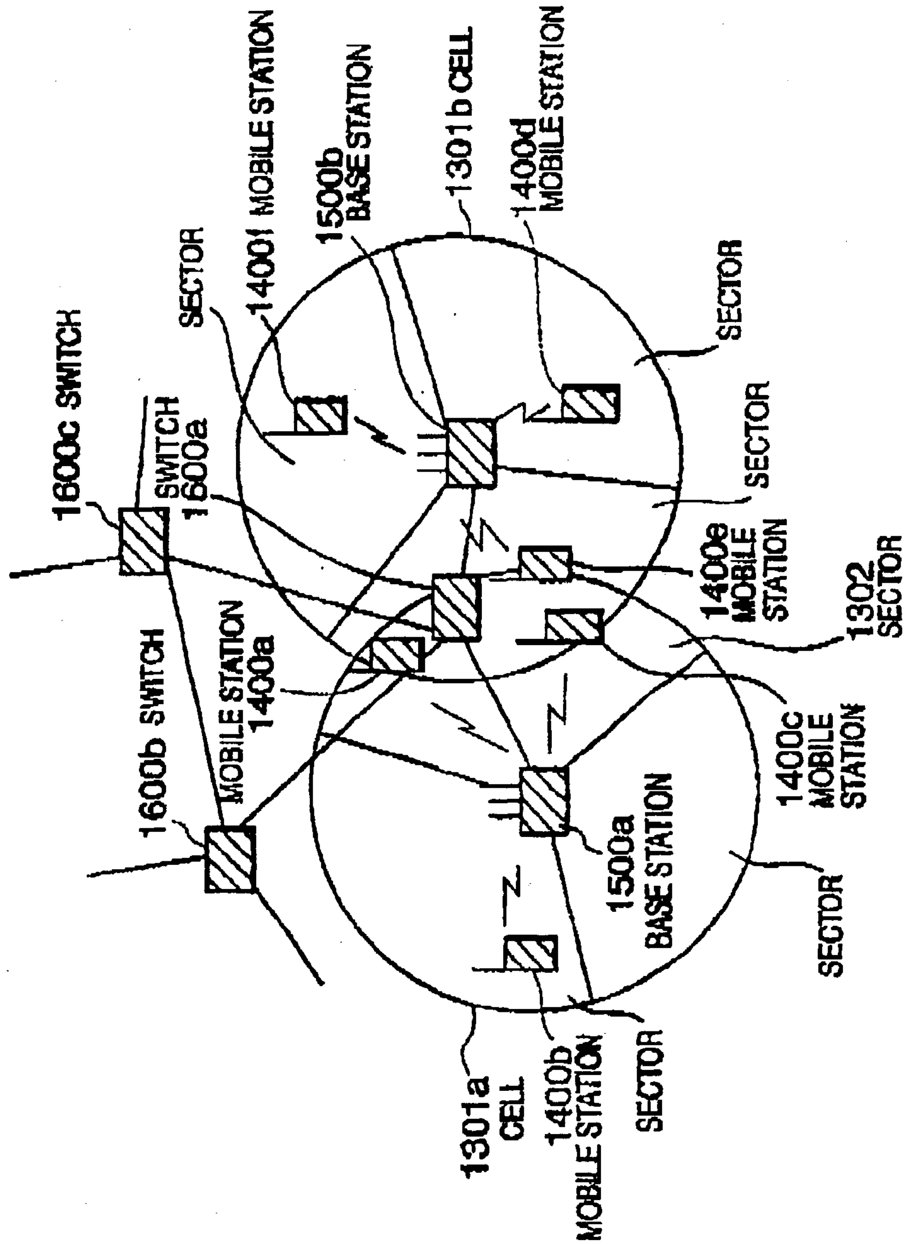

1600c SWITCH
SWITCH 1600a
SECTOR
1400f MOBILE STATION
1500b BASE STATION
1301b CELL
1400d MOBILE STATION
SECTOR
SECTOR
SECTOR
1400e MOBILE STATION
1302 SECTOR
1400c MOBILE STATION
SECTOR
1500a BASE STATION
SECTOR
1301a CELL
1400b MOBILE STATION
SECTOR
MOBILE STATION 1400a
1600b SWITCH

FIG. 14

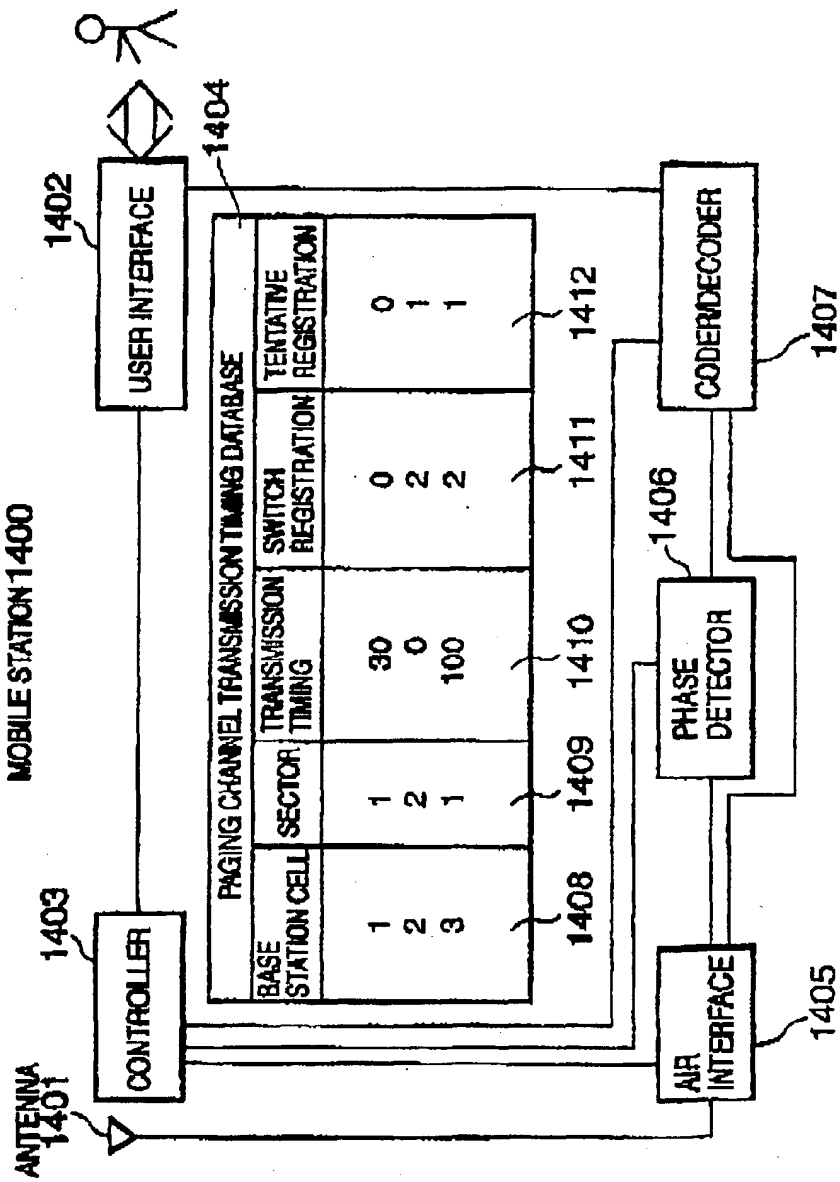

MOBILE STATION 1400
1402
USER INTERFACE
1404
1403
CONTROLLER
PAGING CHANNEL TRANSMISSION TIMING DATABASE
BASE STATION CELL
SECTOR
TRANSMISSION TIMING
SWITCH REGISTRATION
TENTATIVE REGISTRATION
1 2 3
1 2 1
30 0 100
0 2 2
0 1 1
1408
1409
1410
1411
1412
CODER/DECODER
1407
1406
PHASE DETECTOR
AIR INTERFACE
1405
ANTENNA 1401

FIG. 15

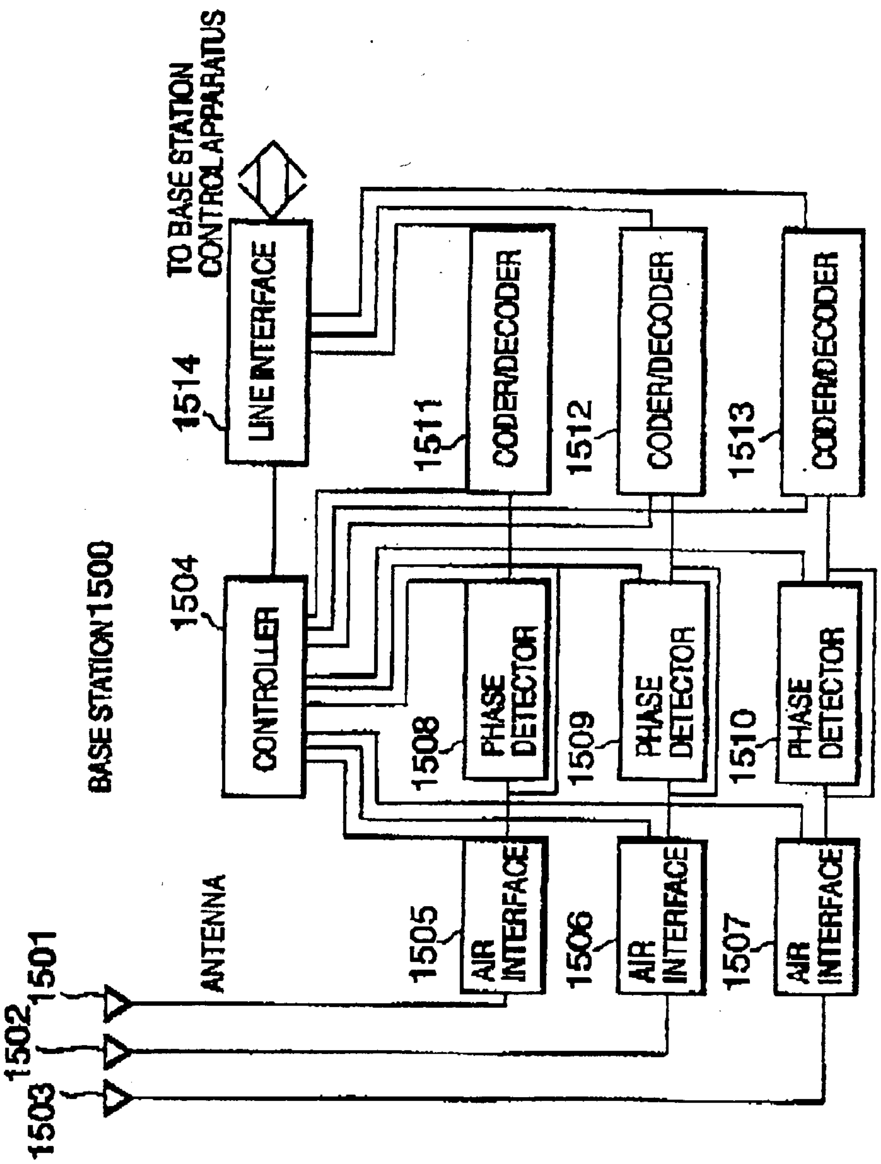

TO BASE STATION
CONTROL APPARATUS
1514
LINE INTERFACE
BASE STATION 1500
1504
CONTROLLER
1511
CODER/DECODER
1512
CODER/DECODER
1513
CODER/DECODER
1508
PHASE DETECTOR
1509
PHASE DETECTOR
1510
PHASE DETECTOR
ANTENNA
1505
AIR INTERFACE
1506
AIR INTERFACE
1507
AIR INTERFACE
1501
1502
1503

FIG. 16

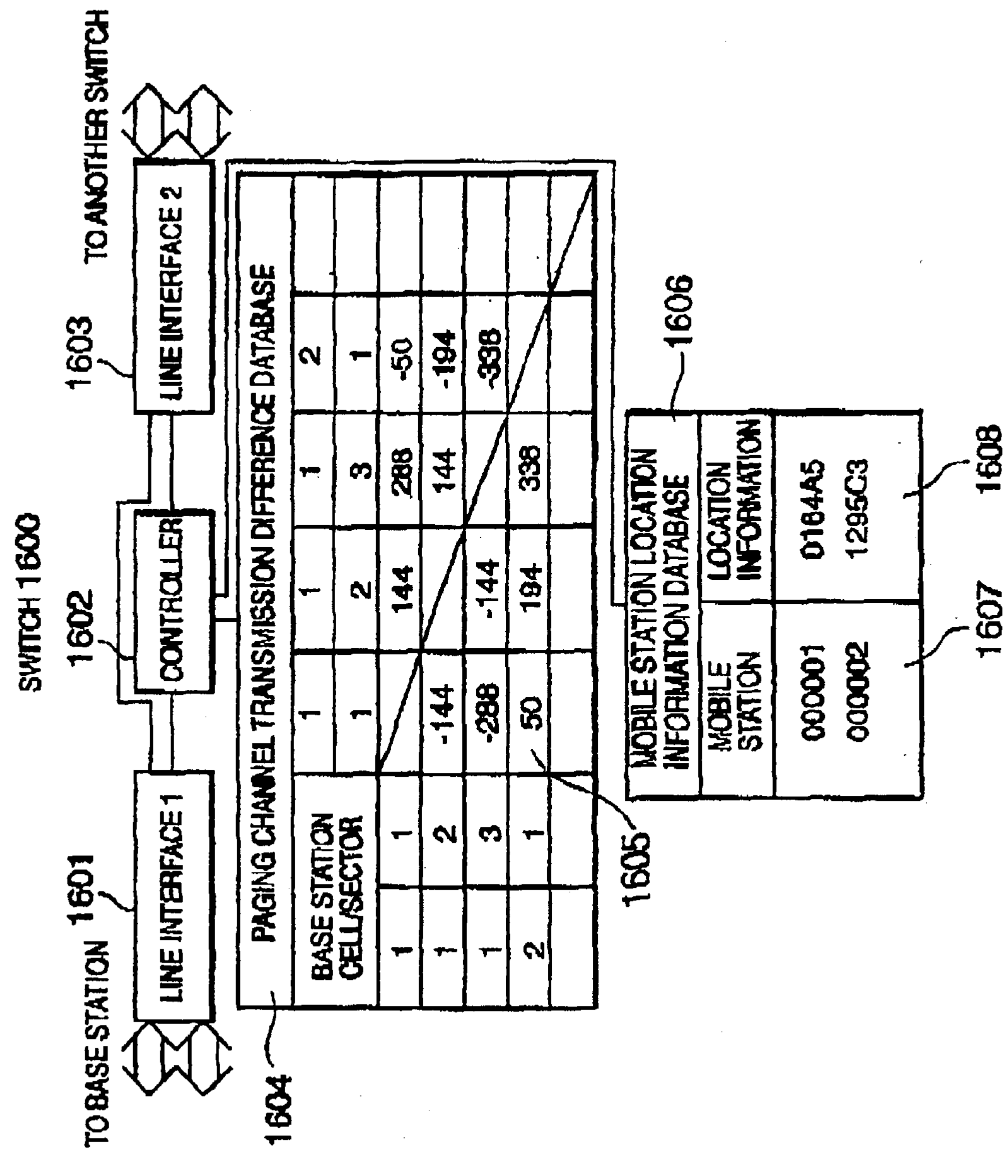
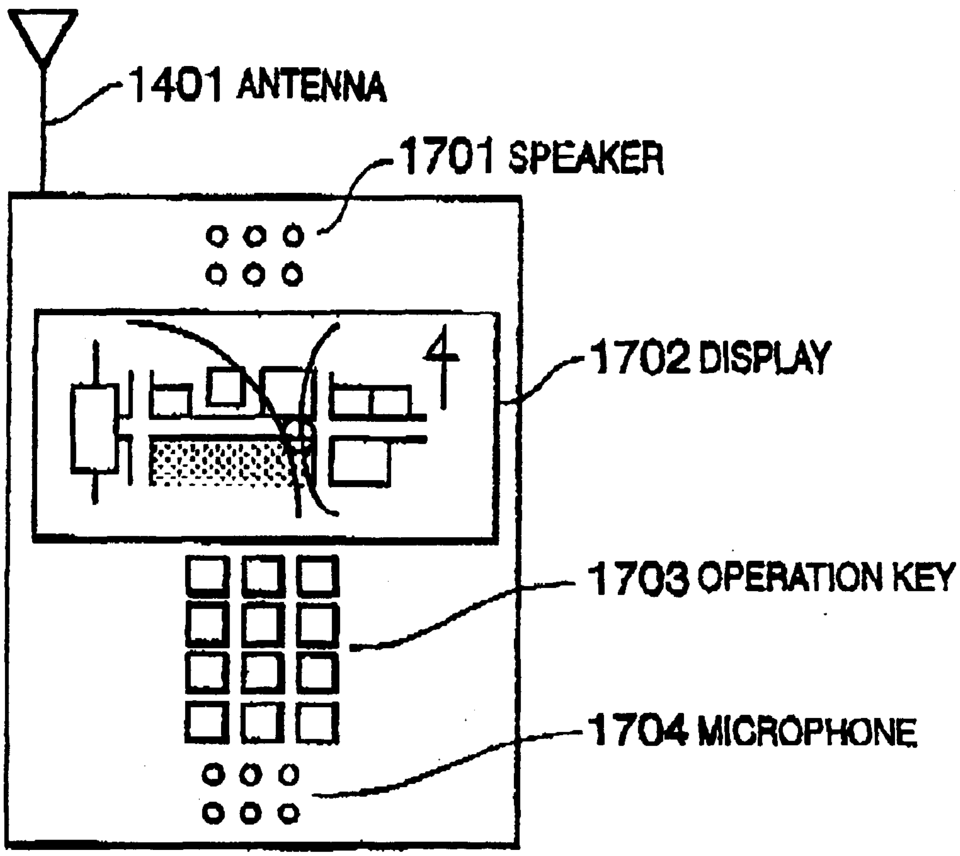

SWITCH 1600
TO BASE STATION
TO ANOTHER SWITCH
1601
LINE INTERFACE 1
1602
CONTROLLER
1603
LINE INTERFACE 2
1604
PAGING CHANNEL TRANSMISSION DIFFERENCE DATABASE
BASE STATION CELL/SECTOR
1 1 1 2
1 2 3 1
1 1 144 288 -50
1 2 -144 144 -194
1 3 -288 -144 -338
2 1 50 194 338
1605
1606
MOBILE STATION LOCATION INFORMATION DATABASE
MOBILE STATION
LOCATION INFORMATION
000001 0164A5
000002 1295C3
1607
1608

FIG. 17



1400 MOBILE STATION

FIG. 18

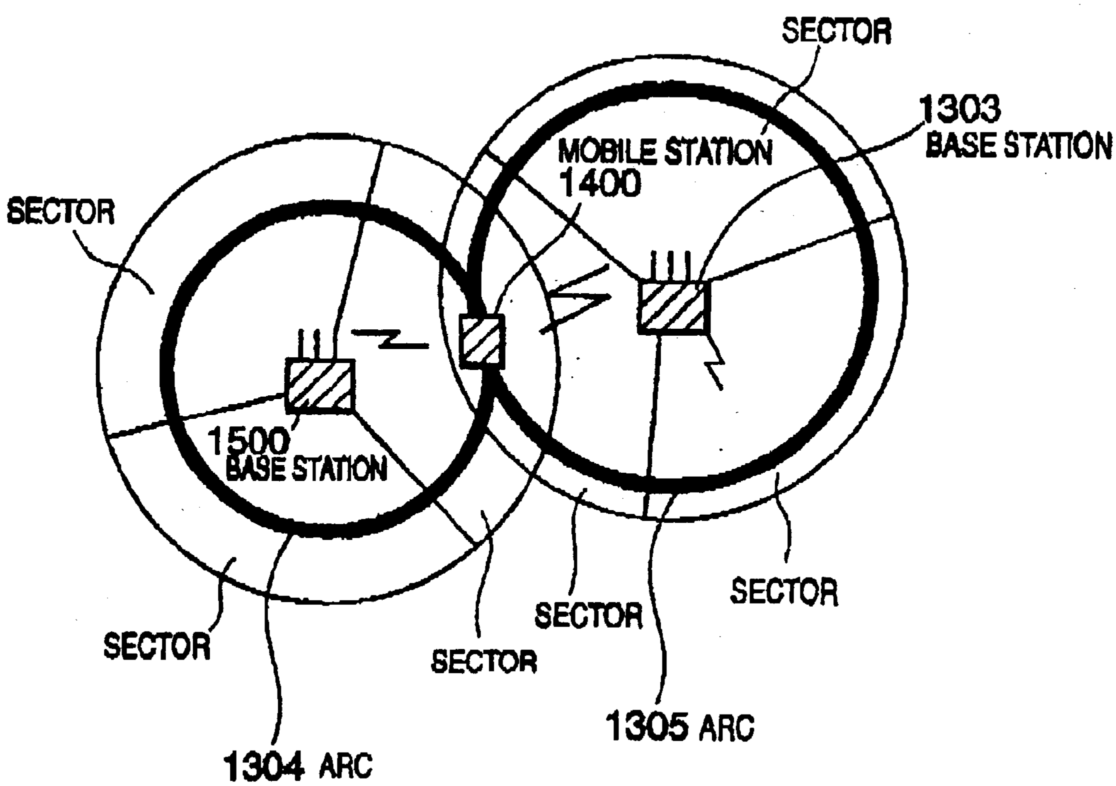

SECTOR
1303
BASE STATION
MOBILE STATION
1400
SECTOR
1500
BASE STATION
SECTOR
SECTOR
SECTOR
SECTOR
1304 ARC
1305 ARC

FIG. 19

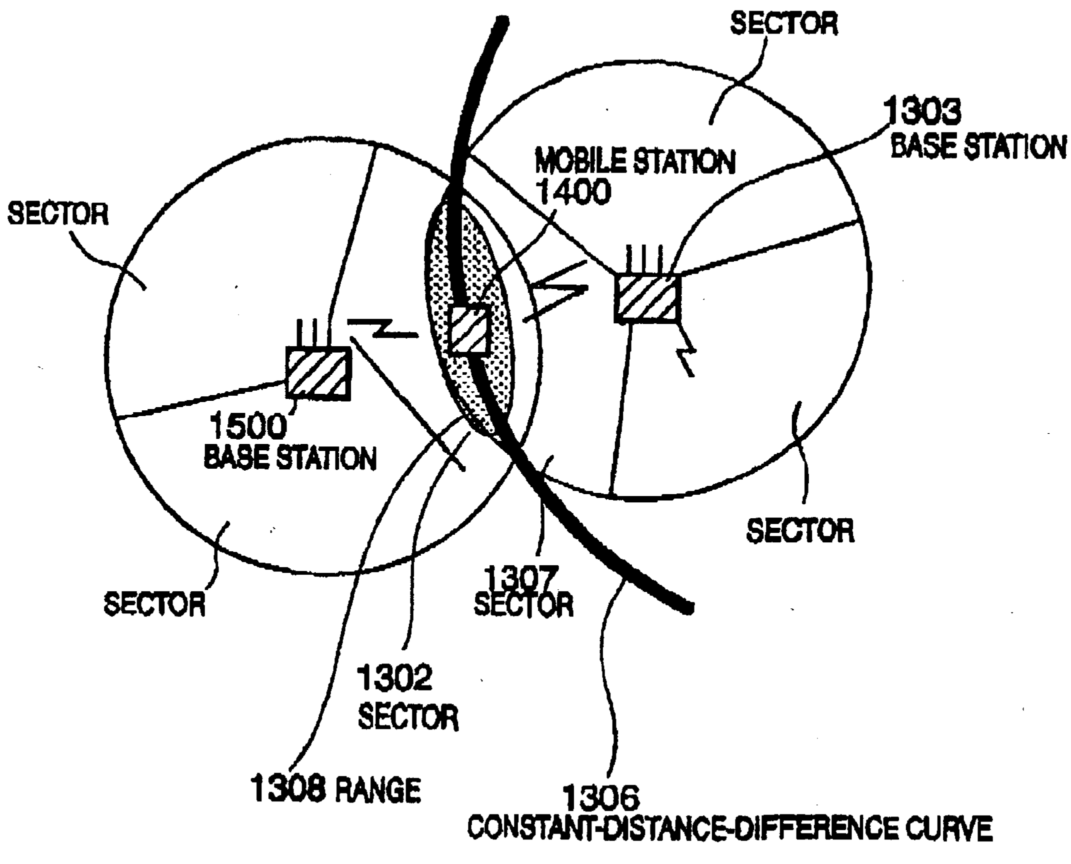
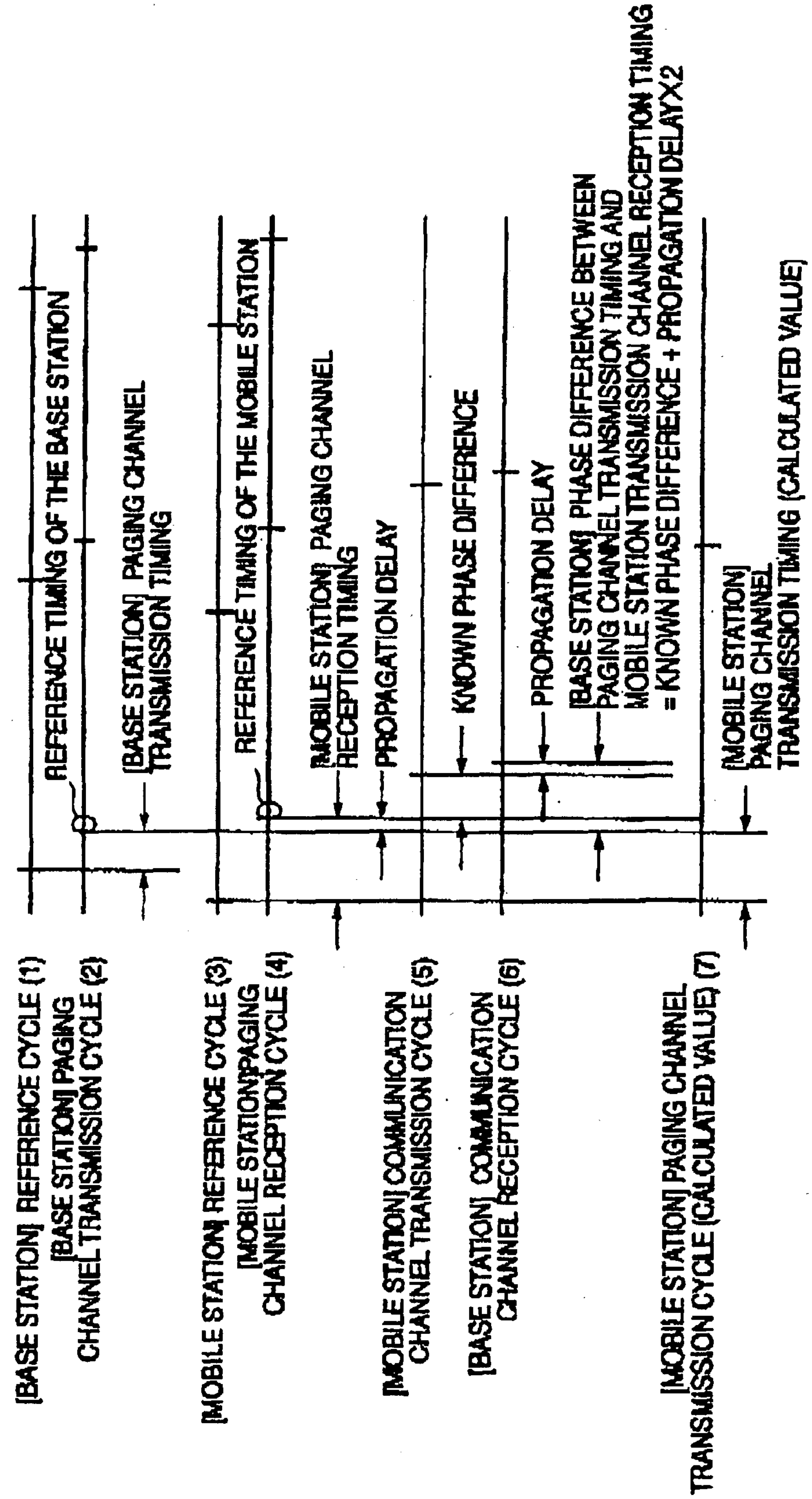

SECTOR
1303
BASE STATION
MOBILE STATION
1400
SECTOR
1500
BASE STATION
SECTOR
SECTOR
1307
SECTOR
1302
SECTOR
1308 RANGE
1306
CONSTANT-DISTANCE-DIFFERENCE CURVE

FIG. 20


[BASE STATION] REFERENCE CYCLE (1)
[BASE STATION] PAGING CHANNEL TRANSMISSION CYCLE (2)
[MOBILE STATION] REFERENCE CYCLE (3)
[MOBILE STATION] PAGING CHANNEL RECEPTION CYCLE (4)
[MOBILE STATION] COMMUNICATION CHANNEL TRANSMISSION CYCLE (5)
[BASE STATION] COMMUNICATION CHANNEL RECEPTION CYCLE (6)
[MOBILE STATION] PAGING CHANNEL TRANSMISSION CYCLE (CALCULATED VALUE) (7)
REFERENCE TIMING OF THE BASE STATION
[BASE STATION] PAGING CHANNEL TRANSMISSION TIMING
REFERENCE TIMING OF THE MOBILE STATION
[MOBILE STATION] PAGING CHANNEL RECEPTION TIMING
PROPAGATION DELAY
KNOWN PHASE DIFFERENCE
PROPAGATION DELAY
[BASE STATION] PHASE DIFFERENCE BETWEEN PAGING CHANNEL TRANSMISSION TIMING AND MOBILE STATION TRANSMISSION CHANNEL RECEPTION TIMING = KNOWN PHASE DIFFERENCE + PROPAGATION DELAYX2
[MOBILE STATION] PAGING CHANNEL TRANSMISSION TIMING (CALCULATED VALUE)

MOBILE COMMUNICATION SYSTEM, MOBILE STATION, AND BASE STATION THAT CALCULATES DISTANCE FROM MOBILE STATION

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a mobile communication system, and in particular to a mobile station that obtains location information by communicating with a base station and a switch, and a base station that calculates distance from a mobile station to which the asynchronous CDMA system is applied.

2. Description of Related Art

Generally, a mobile communication system, represented by a portable telephone system, comprises a mobile station for user to communicate while moving within a radio area or moving from one radio area to another, a base station that forms a radio area by providing a certain area with radio resources for communication, and a switch that forms a communication network by controlling a plurality of base stations and mobile stations in the radio areas of those base stations and connects with other networks including a fixed network. In such a mobile communication system, the base station control function of the switch may be separated from it as a base station control apparatus, which is installed between the base station and the switch. In the following, however, for the sake of convenience of explanation, simply the switch is referred to.

In a mobile communication system, there is a demand for specifying a location of a sender in an emergency or when a mobile station is used illegally. Further, also in ordinary use, it is advantageous to specify a users detailed location, since service such as guidance information can be offered in accordance with that location. Thus, it is very useful to be able to obtain location information of a mobile station.

As a method of obtaining location information of a mobile station, there are mentioned, for example, a method of utilizing a marker embedded in a road or building, and a method of using GPS (Global Positioning System), which is a position system using satellites and used for a car navigation system etc.

However, in the mentioned systems, special devices are required, and communication for a mobile station to obtain location information should be made differently from the ordinary communication, making the processing load relatively large.

As conventional technique that solve the above-mentioned drawbacks for obtaining location information of a mobile station, Japanese Unexamined Patent Application Laid-Open Nos. 7-181242 and 10-322752 are known, for example. These conventional techniques are ones in which location information of a mobile station is obtained by using information on the radio area to which the mobile station belongs and a propagation state of an ordinary channel for mobile communication. These techniques are methods that utilize high-precision timing information in a mobile communication system using a communication channel having that high-precision timing information.

The conventional technique described in the former patent application document 7-181242 is a method in which base stations transmit channels of the same type such that transmission timing differences among base stations are values known in advance, and a mobile station obtains a propagation delay difference for each of plurality of channels by subtracting a transmission timing difference from a reception timing difference, in order to obtain respective differences in distances between the mobile station and the base stations. Further, the conventional technique described in the latter patent application document 10-322752 is a method in which forward-and-return transmission/reception are made between a mobile station and a base station, and the time needed for this transmission-and-reception is measured to obtain a propagation delay and thus to obtain a distance between the mobile station and the base station.

The conventional techniques described in the above two patent application documents premise that a communication channel having high precision timing information is used. As such a representative mobile communication system that uses a communication channel having high precision timing information, a mobile communication system using CDMA (Code Division Multiple Access) is known. CDMA is a technique in which a communication channel is coded with a signal sequence, called a diffusion code, having a change pattern in extremely short times. Accordingly, a communication channel utilizing the CDMA technique has high precision timing information owing to a diffusion code. The CDMA mobile communication system is recently advancing in commercialization, and considered to become the core of International Mobile Telecommunications. Thus, those techniques are very useful as a method of realizing acquisition of location information of a mobile station.

SUMMARY OF THE INVENTION

However, the conventional technique described in the above-described former patent application document 7-181242, i.e., the technique of using transmission channels from a plurality of base stations whose differences in transmission timing are known in advance, has a problem in that its application to a general mobile communication system is difficult.

The reason for it is as follows. Namely, in order that the differences in channel transmission timing among the base stations can be known in advance, it is necessary to satisfy the condition that the mobile communication system is one in which base stations are precisely synchronized with one another and transmit in transmission timing controlled by a switch or the like. However, as a mobile communication system satisfying such a condition, there is only known IS-95, a CDMA mobile communication system standardized in U.S.A., and a general cellular system or the like does not satisfy this condition.

Further, the conventional technique described in the latter patent application document 10-322752, in which a distance between a mobile station and a base station is obtained by measuring a channel propagation delay of transmission/return-reception, has a problem in that it is difficult to apply it to a case in which it is desirable that the latest possible location information can be obtained at all times such as a guide information service according to a current position. This is because, in order to obtain location information of a mobile station, this method must carry out transmission and return reception every time location information is obtained, and, when location information of a mobile station is updated frequently, the processing load of the system as a whole and use of radio resources become large.

Thus, as described above, the method of the conventional technique is limited in its conditions of the applicable mobile communication system, or its processing load and use of a radio resources become large in a case of frequent use.

An object of the present invention is to provide a mobile communication system that solves the above-described problems of the conventional techniques and can obtain a location of a mobile station without requiring a special condition such as synchronization of a plurality of base stations.

Further, another object of the present invention is to provide a mobile station that can calculate its location and a base station that informs the mobile station about a distance between that base station and the mobile station, without requiring a special condition such as synchronization of a plurality of base stations.

Further, another object of the present invention is to provide a mobile communication system in which location information of a mobile station can be frequently obtained, a mobile station that can calculate its location, and a base station that can inform the mobile station about a distance between that base station and the mobile station, while suppressing the processing load and use of radio resources.

According to the present invention, those objects are achieved by providing a following mobile communication system. Namely, the present invention provides a mobile communication system comprising mobile stations, base stations are switches, wherein:

each of the mobile and base stations has means for retaining and updating a cycle that is common to said mobile and base stations although a phase of said cycle is optional for each station, as a reference cycle;

each of the base stations has means for continuing to transmit a paging channel that has a periodic structure of a same cycle as the reference cycle, designating a phase difference from a phase of the reference cycle of the base station, and including information indicating a transmission source in that paging channel;

each of the mobile stations comprises:

means for receiving the paging channel from the base station, for obtaining a phase difference between a phase of the reference cycle of the mobile station itself and a phase of a cycle of the paging channel at a time of the receiving, as a reception timing of the received paging channel, and for obtaining information that is included in the paging channel and indicates a transmission source of the paging channel;

means for obtaining information on a paging channel transmission timing, which is a phase difference between the phase of the reference cycle of the mobile station itself and a phase of the cycle of the paging channel of the base station at a time of transmission, and for recording the obtained information together with the information indicating the transmission source;

means for obtaining information on a paging channel propagation delay, from the information on the reception timing and transmission timing of the paging channel, when a paging channel for which information on a transmission timing is retained in advance, or when information on the transmission timing of the received paging channel is newly obtained; and

means for obtaining information on a distance between the mobile station itself and the base station, based on the information on the propagation delay of the paging channel and the information indicating the transmission source of the paging channel.

Measurement results obtained from processing required for ordinary communication control for the mobile communication system, such as measurement of a paging channel reception timing and measurement of a propagation delay between a mobile station and a base station, may be diverted to the above-described procedures.

Accordingly, the present invention can obtain location information of a mobile station, with relatively lower processing loads. Further, variations of the above-mentioned means may be used in accordance with setting status of a communication channel from moment to moment. By this, the necessity of dedicated radio resources can be decreased.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a flowchart for explaining a main procedure in a mobile station according to an embodiment of the present invention;

FIG. 2 is a flowchart for explaining an example of a procedure for obtaining paging channel transmission timing in FIG. 1;

FIG. 3 is a flowchart for explaining an example of a procedure for obtaining paging channel transmission timing in FIG. 1;

FIG. 4 is a flowchart for explaining an example of a procedure for obtaining paging channel transmission timing in FIG. 1;

FIG. 5 is a flowchart for explaining an example of a procedure for calculating paging channel propagation delay information in FIG. 1;

FIG. 6 is a flowchart for explaining an example of a procedure for calculating paging channel propagation delay information in FIG. 1;

FIG. 7 is a flowchart for explaining a procedure for recording paging channel transmission timing difference in a mobile station according to an embodiment of the present invention;

FIG. 8 is a flowchart for explaining a procedure for transmitting a paging channel in a base station according to an embodiment of the present invention;

FIG. 9 is a flowchart for explaining a base station's procedure corresponding to the mobile station's procedure shown in FIG. 2;

FIG. 10 is a flowchart for explaining a base station's procedure corresponding to the mobile station's procedure shown in FIG. 3;

FIG. 11 is a flowchart for explaining a base station's procedure corresponding to the mobile station's procedure shown in FIG. 4;

FIG. 12 is a flowchart for explaining a switch's procedure corresponding to the mobile station's procedure shown in FIG. 7;

FIG. 13 is a block diagram showing a conceptual configuration of a CDMA mobile communication system to which the present invention is applied;

FIG. 14 is a block diagram showing a configuration of a mobile station according to one embodiment of the present invention;

FIG. 15 is a block diagram showing a configuration of a base station according to one embodiment of the present invention;

FIG. 16 is a block diagram showing a configuration of a switch according to one embodiment of the present invention;

FIG. 17 is a view for explaining an appearance of a mobile station according to one embodiment of the present invention;

FIG. 18 is a view for explaining a principle of obtaining location information of a mobile station;

FIG. 19 is a view for explaining a principle of obtaining location information of a mobile station; and

FIG. 20 is a timing chart for explaining a relation between transmission and reception timings for respective channels and for explaining a principle of obtaining channel propagation delay differences and transmission timing.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following, embodiments of the mobile communication system according to the present invention will be described in detail referring to the drawings.

FIG. 1 is a flowchart for explaining a main procedure in a mobile station according to an embodiment of the present invention. FIGS. **2**, **3**, and **4** are flowcharts for explaining examples of a procedure for obtaining paging channel transmission timing in FIG. **1**. FIGS. **5** and **6** are flowcharts for explaining examples of a procedure for calculating paging channel propagation delay information in FIG. **1**. FIG. **7** is a flowchart for explaining a procedure for recording paging channel transmission timing difference in a mobile station according to an embodiment of the present invention. FIG. **8** is a flowchart for explaining a procedure for transmitting a paging channel in a base station according to an embodiment of the present invention. FIGS. **9**, **10** and **11** are flowcharts for explaining base station's procedures corresponding to the mobile station's procedures shown in FIGS. **2**, **3** and **4**. FIG. **12** is a flowchart for explaining a switch's procedure corresponding to the mobile station's procedure shown in FIG. **7**. FIG. **13** is a block diagram showing a conceptual configuration of a CDMA mobile communication system to which the present invention is applied. FIG. **14** is a block diagram showing a configuration of a mobile station according to one embodiment of the present invention. FIG. **15** is a block diagram showing a configuration of a base station according to one embodiment of the present invention. FIG. **16** is a block diagram showing a configuration of a switch according to one embodiment of the present invention. FIG. **17** is a view for explaining an appearance of a mobile station according to one embodiment of the present invention. FIGS. **18** and **19** are views for explaining principles of obtaining location information of a mobile station. And, FIG. **20** is a timing chart for explaining a relation between transmission and reception timings for respective channels and for explaining a principle of obtaining channel propagation delay differences and transmission timing. In FIGS. **13**–**17**, a reference numeral **1301** refers to a cell, **1302** to a sector, **1400** to a mobile station (MS), **1401** and **1501**–**1503** to antennas, **1402** to a user interface, **1403**, **1504** and **1602** to controllers, **1404** to a paging channel transmission timing database, **1405** and **1505**–**1507** to air interfaces, **1406** and **1508**–**1510** to phase detectors, **1407** and **1511**–**1513** to coder/decoders, **1500** to a base station, **1514**, **1601** and **1603** to line interfaces, **1600** to a switch, **1604** to a paging channel transmission timing difference database, **1606** to a mobile station location information database, **1701** to a speaker, **1702** to a display, **1703** to an operation key, and **1704** to a microphone.

As shown in FIG. **13**, the CDMA mobile communication system to which the present invention is applied is constructed to include a plurality of mobile stations **1400**–**1400*f***, a plurality of base stations **1500**, and a plurality of switches **1600**. A base station **1500** has a cell **1301** of a generally circular shape as a radio area within which that base station can offer services to mobile stations **1400*a***. In the example shown, the cell **1301** is divided into and consists of three fan-shaped sectors **1302**. The mobile station **1400*a*** shown in the figure belongs to the sector **1302** of the cell **1301*a*** of the base station **1500*a***, and, at the same time, belongs to the sector of the cell **1301*b*** of the adjacent base station **1500*b***. As the mobile station **1400*a*** moves, it changes the cell and sectors to which it belongs, and changes the base station as the communication partner depending on the cell and sector to which the mobile station belongs at that moment.

As shown in FIG. **14**, the mobile station **1400** comprises an antenna **1401**, a user interface **1402**, a controller **1403**, a paging channel transmission timing database **1404** provided in a memory within the controller **1403** or an external memory (not shown) that can be accessed from the controller, an air interface **1405**, a phase detector **1406**, and a coder/decoder **1407**.

In the mobile station **1400** shown in FIG. **14**, the coder/decoder **1407** has functions of coding a transmission channel with a signal sequence called a diffusion code characteristic to the CDMA system and of decoding a received channel with the same diffusion code as one used by a transmitter to code the transmission channel. The channel that has been coded with a diffusion code has a periodic structure, and decoding of this channel requires phase information for decoding in accordance with the periodic structure of this channel, in addition to the diffusion code used for coding. The phase detector **1406** is for detecting the phase information of this received channel. There are two methods for the phase detector **1406** to detect the phase information of the received channel.

A first method is one of optionally searching within a channel cycle to detect the phase information of the received channel. This method is employed only when a paging channel is received. In the present specification, a paging channel is a signal for specifying a base station and that signal is required for making radio communication between the base station and a mobile station. By receiving this paging channel, a mobile station can know which base station accommodates that mobile station. A second method is one in which, when the phase information designated by the transmitting side is known in advance and a predicted value of the phase information of the received channel to be detected can be obtained, the phase information of the received channel is detected by carrying out the detection centering about this predicted value and correcting the error. This method is used when a communication channel other than the paging channel is received.

The air interface **1405** and the antenna **1401** are for transmitting and receiving a coded channel over the air. The controller **1403** carries out various controls to make ordinary communication and to obtain location information of the mobile station. The user interface **1402** is used by a user to input data and to operate the mobile station, and provides various outputs including presentation of location information to the user. Further, the paging channel transmission timing database **1404** is a database storing base station cell numbers **1408**, sector numbers **1409**, paging channel transmission timings **1410**, switch registration information **1411**, and tentative registration information (flags) **1412**.

As shown in FIG. **15**, a base station **1500** comprises antennas **1501**–**1503**, a controller **1504**, air interfaces **1505**–**1507**, phase detectors **1508**–**1510**, coder/decoders **1511**–**1513**, and a line interface **1514**. The coder/decoders **1511**–**1513**, the phase detectors **1508**–**1510**, the air inter-

faces **1505–1507**, and the antennas **1501–1503** have the similar functions of the corresponding components of the mobile station **1400**, each component being provided in a set of three. This is because one cell consists of three sectors, and those components are provided to correspond to respective sectors. Namely, when a cell consists of a plurality of sectors, the base station transmits respectively different paging channels for the sectors, and setting of other communication channels and transmission/reception are carried out for each sector separately. Further, the line interface **1514** has a function of communicating with a switch as a base station control apparatus.

In the above-described mobile station and base station, the controllers **1403**, **1504** provided to those stations receive a report on received channel phase information from the phase detectors **1406**, **1508–1510**, and instruct the coder/decoders **1407**, **1511–1513** about transmission channel coding start timing. At this time, the received channel phase information and the transmission channel coding start timing are expressed in terms of a phase relative to a reference cycle measured by the respective controller **1403** and **1504** of the mobile station **1400** and the base station **1500**. Those values are used respectively as the reception timing and transmission timing relating to the present invention.

As shown in FIG. **16**, the switch **1600** comprises line interfaces **1601**, **1603**, a controller **1602**, a paging channel transmission timing difference database **1604**, and a mobile station location information database **1604**, those databases being stored in a memory within the controller or an external memory (not shown) that can be accessed from the controller.

The line interfaces **1601**, **1603** have a function for the switch **1600** to communicate with a base station **1500** or an adjacent other switch or another network such as a fixed network. The paging channel transmission timing difference database **1604** records information on transmission timing differences between paging channels between sectors of the cells of the base stations, into a transmission timing difference record area **1605**. Further, the mobile station location information database **1606** records mobile station numbers relating to mobile stations whose location information has been obtained in the switch **1600**, and their location information, relating those numbers and location information to each other, into a recording area of mobile station numbers **1607** and a recording area of location information **1608**, respectively.

An appearance of the mobile station **1400** is shown in FIG. **17**. As shown in FIG. **17**, the mobile station **1400** is provided with a speaker **1701**, a display **1702**, operation keys **1703**, and a microphone **1704**. All these correspond to the user interface **1402** described referring to FIG. **14**.

Next, referring to the flowcharts shown in FIGS. **1–12**, processing operations of various parts of the mobile station shown in FIG. **14**, the base station shown in FIG. **15**, and the switch shown in FIG. **16** will be described.

First, referring to the flowchart of FIG. **8**, processing operation in the base station **1500** for transmitting a paging channel will be described.

(1) To the coder/decoders **1511–1513**, the controller **1504** of the base station **1500** designates a diffusion code and transmission timing for a paging channel and diffusion codes and reception timings of communication channels from the respective mobile stations to the base station **1500**. Here, as the paging channel transmission timing, on optional value can be designated. However, the reception timings from the mobile stations should be prescribed values based on the paging channel transmission timing. This will be described later (Step **800**).

(2) Next, the controller **1504** informs the coder/decoders **1511–1513** about paging channel transmission contents including transmission source cell/sector numbers and a diffusion code and timing information for a reception channel from a mobile station **1400**, and instructs the air interfaces **1505–1507** to start transmissions. The paging channel is coded through the coder/decoders **1511–1513**, and thereafter, transmission from the air interfaces **1505–1507** using the antennas **1501–1503** is started. From that time on, the base station **1500** continues to transmit the paging channel in a constant cycle (Step **801**).

Next, referring to the flowchart shown in FIG. **1**, processing operation in the mobile station **1400** will be described. The mobile station operates when it receives the paging channel from the base station.

(1) The controller **1403** of the mobile station **1400** instructs the air interface **1405** to start receiving the paging channel from the base station **1500**. The air interface **1405** receives the paging channel through the antenna **1401**, and delivers the information of the received paging channel to the phase detector **1406**. At that time, the controller **1403** designates a predetermined plurality of diffusion codes for paging channels, for the phase detector **1406** and the coder/decoder **1407**, in preparation for later acquisition of paging channel reception timing and information contained in the paging channel. This designation is carried out at the same time with or prior to instructing the air interface **1405** to start receiving the paging channel (Step **100**).

(2) Next, the phase detector **1406** carries out phase detection on the paging channel using the diffusion code designated by the controller **1403**, and delivers the detected phase information and the paging channel to the coder/decoder **1407**. At the same time, the phase detector **1406** detects the leading timing of the paging channel cycle according to a sequence of the plurality of diffusion codes, and reports this timing, as the paging channel reception timing, to the controller **1403**. The coder/decoder **1407** uses the phase information delivered from the phase detector **1406** and the diffusion code designated by the controller **1403**, to decode the paging channel delivered also from the phase detector **1406**, and delivers the decoded paging channel to the controller **1403**. Then, the controller **1403** obtains the information contained in the paging channel such as the cell/sector numbers of the base station as the transmission source of that paging channel (Step **101**).

(3) Next, the controller **1403** uses the cell number **1408** and the sector number **1409** of the base station, as keys to retrieve the cell/sector of the base station as the transmission source of the paging channel, from the paging channel transmission timing database **1404**. Thus, the controller **1403** investigates if the cell/sector of the base station as the transmission source of that paging channel have been registered in the paging channel transmission timing database **1404** (Steps **102**, **103**).

(4) When, as a result of the investigation in Step **103**, the cell/sector of the base station are proved to be non-registered, then, the controller **1403** registers the cell/sector numbers of this base station into the base station cell numbers **1408** and the sector numbers **1409** of the paging channel transmission timing database **1404**. At this time, the transmission timing **1410** of the paging channel is kept empty (Step **104**).

(5) After the process of Step **104**, or when the result of the investigation confirms the registration, the controller **1403**

refers to the result of the retrieval from the paging channel transmission timing database in Step **103**, to investigate if the transmission timing of the received paging channel has been registered or not. Usually, updating of the paging channel transmission timing that has been already registered it not necessary. However, in the present invention, updating of the paging channel transmission timing can be carried out easily, accompanying the processes for making ordinary communication, as will be described below. Accordingly, for example, when the precision of the reference cycle is considered to be insufficient for long time continuous use, and this investigation is carried out at a point of time when a process is under execution while updating of the paging channel transmission timing can be carried out accompanying it, then it may be decided to update the paging channel transmission timing (Step **105**).

(6) When, as a result of the investigation in Step **105**, the paging channel transmission timing is proved to be non-registered, or when the judgement of updating is made, then, the various parts of the mobile station **1400**, the base station **1500**, and the switch **1600** cooperate to carry out a procedure for the mobile station to obtain the paging channel transmission timing. With respect to detail of this procedure, there are three variations, as will be described below (Step **106**).

(7) After the process of Step **106**, or when the result of the investigation in Step **105** confirms the registration and there is no need of updating, then, the controller **1403** of the mobile station **1400** uses the transmission timing information obtained in the procedure of Step **106** for obtaining the paging channel transmission timing, or the transmission timing information recorded in the paging channel transmission timing database, in order to carry out a procedure for calculating a paging channel propagation delay or propagation delay difference. The procedure of calculating the propagation delay and the procedure of calculating the propagation delay difference will be described later (Step **107**).

(8) Next, the control part **1403** calculate the distance from the transmission source base station, based on the paging channel propagation delay, or calculates difference in distances from the transmission source base stations, based on the propagation delay difference. Acquisition of distance or distance difference from propagation delay or propagation delay difference can be easily carried out using the relation of "distance=velocity of light×propagation delay". The distance calculated here shows that the mobile station exists in either a location on an arc **1304** within a cell centering at a paging channel transmission source base station **1500** or a location on an arc **1305** within a cell centering at a paging channel transmission source base station **1303**, as shown in FIG. **18**. Further, the distance difference shows that the mobile station exists in either location on a constant-distance-difference curve **1306** that is constant with respect to the difference between distances from respective transmission source base stations **1500**, **1303** for two paging channels. In this case, it is also provided to limit a range **1308** on the constant-distance-difference curve **1306** (Step **108**).

(9) Next, the controller **1403** uses a distance from a base station or a distance difference between distances from a plurality of base stations and a map or geographic information such as coordinates of each base station, in order to obtain the location information of the mobile station **1400**. The controller **1403** delivers the location information of the mobile station to the user interface **1402** and instructs the user interface **1402** to output it. The user interface **1402** outputs the location information using one of or both the display **1702** and the speaker **1701** (Steps **109**, **110**).

In a display example of the display **1702** of the mobile station shown in FIG. **17**, the location of the mobile station **1400** is indicated by O-mark on a map. To make such a display, the controller **1403** may previously retain map information on areas in which a user may use the mobile station and coordinates of each base station in the neighborhood. And, in the process of the above-described Step **109** for obtaining the location information of the mobile station, the distances or distance differences from the base stations and the coordinates of the base stations are used to overlay the above-mentioned arcs or constant-distance-difference curve on the map information, and then, the location information is obtained as a result of a process of specifying the location of the mobile station on the map.

Thus-described method requires at least two of arcs and/or constant-distance-difference curves, in total. However, as shown in FIGS. **18** and **19**, it is possible to employ a method in which information on cover areas and directions of sectors is held further by the controller **1403** and overlaid on the map similarly, so that even single arc or constant-distance-difference curve specifies the location of the mobile station. Or, in another method, a switch **1600** may retain coordinates of each base station under its control, information on cover areas and directions of the sectors, and map information about the circumference of the area including the base stations under its control. Then, the mobile station **1400** and the switch **1600** communicate with each other to calculate the location information. This method can be realized as follows. Namely, in the above-described method, the map information, the base station coordinate information and the like are retained in advance in the mobile station's controller **1403**. The switch's controller **1602** to report the map information, base station coordinate information and the like when those pieces of information are required for calculation of location information. In addition, the mobile switch controller **1403** informs the switch's controller **1602** about propagation delay information or distance information. The switch's controller **1602** calculates the mobile station's location on the map, using this propagation delay information or the distance information and reports the result to the mobile station's controller **1403**.

Further, mobile station location information may be managed on the side of the network for the reason of, for example, providing service based on the mobile station location information. Then, when the switch's controller **1602** acquires mobile station location information, the switch's controller directly records it into the mobile station location information database **1606**. When the mobile station's controller **1403** obtains the mobile station location information, the result is reported to the switch's controller **1602**, which then records the information into the mobile station location information database **1606**, in addition to performing other procedures.

Next, detail of the above-mentioned procedure in Step **106** for the mobile station to obtain the paging channel transmission timing will be described giving three variations and referring to the flowcharts shown in FIGS. **2**–**4**.

First, referring to the process flow shown in FIG. **2** with respect to the mobile station, detail of the procedure of the above-mentioned Step **106** will be described according to the first variation.

(1) When the process of Step **106** for obtaining the paging channel transmission timing is started, the controller **1403** of

the mobile station **1400** designates the diffusion code and transmission timing for the coder/decoder **1407** and instructs the air interface **1405** to transmit. The air interface **1405** transmits this channel through the antenna **1401** (Step **200**).

In this process, the diffusion code and transmission timing designated by the controller **1403** for the coder/decoder **1407** are as follows. First, the diffusion code is the mobile station transmission channel diffusion code obtained from the paging channel of the base station to which the mobile station **1400** is going to make transmission in the process of detecting the paging channel reception timing and its contents in Step **101**. Further, the transmission timing is obtained as follows. Namely, a phase difference between the base station paging channel transmission timing obtained from the received contents of the same paging channel and the mobile station transmission channel reception timing is used together with the reception timing of the paging channel obtained at the same time as the transmission timing. Thus, the reception timing is shifted by the phase difference, to obtain the transmission timing in question. On the other hand, in the process of designating the reception timing in the base station **1500** in Step **800** described referring to FIG. **8**, the reception timing is designated by shifting the paging channel transmission timing by the same phase difference.

Thus-described procedure is not specific to the present invention, but a common method of designating transmission/reception timing in a case where communication is carried out between a mobile station and a base station in an asynchronous CDMA mobile communication system. Here, the reason for such designation of transmission/reception timing in the mobile station and the base station will be described in the following.

The transmission/reception timing that the base station can designate is a phase relative to the reference cycle of the base station, and, on the other hand, the transmission/reception timing that the mobile station designates is a phase relative to the reference cycle of the mobile station. The phase difference between the reference cycle of the base station and the reference cycle of the mobile station may take any values since the base station and the mobile station are not synchronized with each other. For this reason, in order to uniformly arrange transmission/reception timings of the channels except for the paging channel, with respect to the actual time (namely, in order to synchronize the base station's reference timing with the mobile station's reference timing), the following operation is required, for example.

Namely, a phase difference of a certain value is commonly owned by the mobile station and the base station. As the transmission/reception timing of the mobile station, there is used a value obtained by shifting the paging channel reception timing by a phase difference corresponding to the propagation delay shown in FIG. **20** (4). As the transmission/reception timing of the base station, there is used the value of the paging channel transmission timing.

FIG. **20** shows relations of respective reference cycles of the base station and the mobile station with the transmission/reception timing of the paging channel and a communication channel transmitted from the mobile station to the base station. As shown in FIG. **20**, the reference operation clocks of the base station and the mobile station and each channel have the same cycle with respective individual phases, and phase differences between those phases are not known as described above. However, when the base station's transmission timing of the paging channel and the reception timing for the mobile station to receive the paging channel from the base station are determined, those channels can be regarded as generally-synchronized timing although they have variable errors corresponding to the propagation delay of the paging channel between the base station and the mobile station. This can be taken as the reference timing for designating transmission/reception timing of each communication channel in the mobile station and base station. The above is why the transmission/reception timing in the mobile station and the base station is designated based on the transmission/reception timing of the paging channel.

(2) The communication channel transmitted from the mobile station in the process of Step **200** is received by the base station. The procedure of the base station shown in FIG. **9** is started. Namely, one of the air interfaces, for example the air interface **1505**, corresponding to the base station's cell/sector as the destination of the mobile station, and the phase detector **1508** receive the channel from the mobile station through the antenna **1501** (Step **900**).

As shown in the timing chart of FIG. **20** (6), the reception timing of the actual communication channel in the base station becomes timing that is delayed by a phase corresponding to the sum total of a propagation delay of the paging channel transmitted from the base station to the mobile station with the reception timing designated by the base station (FIG. **20** (4)), a propagation delay of the mobile station transmission channel transmitted from the mobile station to the base station (FIG. **20** (6)), and timing required by the mobile station between the reception of the paging channel from the base station and the transmission of the communication channel to the base station (FIG. **20** (5)). Accordingly, the phase detector **1508** corrects this before reception.

The phase detector **1508** reports the actual reception timing to the controller **1504**. The controller **1504** compares the reception timing from the mobile station in the process of Step **800** described referring to FIG. **8** (as shown in FIG. **20** (2), the paging channel transmission from the base station is designated as the reception timing of the communication channel from the mobile station) with the actual reception timing, to obtain the forward-and-return propagation delay between the base station and the mobile station contained in the actual reception timing (Step **901**).

See FIG. **20** (7).

The phase difference between the base station paging channel transmission timing and the mobile station transmission channel reception timing=known phase difference (timing required for the mobile station from receiving the paging channel from the base station to transmitting the communication channel to the base station)+the propagation delay=2

(3) Next, the controller **1504** informs the mobile station's controller **1403** about the propagation delay obtained in Step **901**. Here, as the propagation delay, the controller **1504** reports an one-way propagation delay obtained by dividing the forward-and-return propagation delay by 2. When a channel different from the paging channel is used for this reporting, it is necessary that the diffusion code and the transmission timing are designated for the coder/decoder **1511** and a transmission instruction is given to the air interface **1505**. In this case, prior to the process of receiving the propagation delay in the below-described Step **201**, it is necessary that the mobile station designates the diffusion code and the reception timing to the phase detector **1406** and the coder/decoder **1407** and instructs the air interface **1405** to start receiving. It is also necessary that the diffusion code and phase difference for the paging channel transmission/

reception timing are included in the contents of the paging channel for example, in order to make them consistent between the base station and the mobile station (Step **902**).

(4) Next, the controller **1403** of the mobile station **1400** obtains the propagation delay sent in the above-described Step **902** in the base station, and removes this propagation delay from the paging channel reception timing, to obtain the paging channel transmission timing relative to the mobile station's reference cycle. As shown in FIG. **20**, this paging channel transmission timing coincides with the paging channel transmission timing at the time of the transmission in the base station, and does not change. Accordingly, the once-obtained value can be used as it is from that time on, as long as the reference cycles and the paging channel cycles are exactly same between the mobile station and the base station (Steps **201**, **202**).

(5) Next, in the case that the paging channel transmission source base station cell/sector numbers are newly registered or updated in the process of Step **104** described referring to FIG. 1, the controller **1403** records the above-mentioned paging channel transmission timing into the paging channel database **1404**, as the transmission timing **1410** corresponding to the base station cell number **1408** and the sector number **1409**. Those base station cell number **1408** and the sector number **1409** has been obtained in the process of retrieving the paging channel transmission source base station cell/sector numbers in Step **103** (Step **203**).

The above describes the detail of the processing according to the first variation of Step **106** for obtaining the paging channel transmission timing. However, transmission/reception that employs such procedure and terminates at the mobile station and the base station and the measurement of the propagation delay in that transmission/reception are common communication procedures in the asynchronous CDMA mobile communication system, and carried out for setting a communication channel for user data, for example. For this reason, the acquisition of the location information of the mobile station for the present invention can be carried out accompanying the common processing. Thus, it can be carried out very efficiently, suppressing the load of the processing and use of radio resource.

Next, referring to the process flow shown in FIG. **3** with respect to the mobile station and the process flow shown in FIG. **10** with respect to the base station, detail of the procedure of the above-mentioned Step **106** according to the second variation will be described.

According to the second variation, the procedure of the above-mentioned Step **106** can be carried out when a channel synchronizing process is under execution. For example, when, for a channel expected to carry out continuous transmission/reception, such as a user data communication channel, phasing between a mobile station and a base station is carried out with respect to transmission/reception timing before starting that transmission/reception and the phased state is maintained until the end of the communication, then, the channel synchronizing process is the mentioned phasing process that is carried out before starting the transmission/reception. The process of soft hand-over is characteristic to the CDMA mobile communication system. In that process, channels of a plurality of cells/sectors are synthesized as a whole into one channel in the neighborhood of a boundary between cells/sectors, etc. and synchronization is carried out for each channel called hand-over branch which is the object of the synthesis. The procedure according to the second variation described below is particularly suitable for carrying out accompanying the synchronizing process for hand-over branches.

(1) It is assumed that, when the process of Step **106** for obtaining the paging channel transmission timing is going to be started, the mobile station and the base station carry out the synchronizing process for hand-over branches in Steps **300** and **1000**, as described above. At this time, the controller **1504** of the base station designates a diffusion code and transmission/reception timing for the air interface **1506**, the phase detector **1509**, and the coder/decoder **1512**. These diffusion code and transmission/reception timing are the values that have been arranged uniformly with the mobile station **1400** in advance. Similarly to the procedure of the first variation, the transmission/reception timing is designated based on the transmission/reception timing of the paging channel. At the same time with establishment of synchronization, the phase detector **1509** and the coder/decoder **1512** start to receive the channel (Step **1001**).

(2) Next, the controller **1504** of the base station obtains the actually-received reception timing from the phase detector **1509**, and compares this actual reception timing with the reception timing designated for the synchronizing process, to obtain a propagation delay. Thus, the forward-and-return propagation delay between the mobile station and the base station can be obtained on the same grounds as the procedure of the first variation (Step **1002**).

(3) Next, the controller **1504** of the base station informs the mobile station's controller **1403** of the propagation delay. This can be carried out using the channel for which synchronization has been established, without using a dedicated communication channel, and accordingly, without occupying the radio resources corresponding to the dedicated communication channel. In a case where the channel terminates at the mobile station and the switch, for example, when the switch synthesizes hand-over branches that extend through a plurality of base station cells by the soft handover, the base station's controller **1504** can report this to the mobile station's controller **1403** through the switch's controller **1602** (Step **1003**).

(4) From that time on, the controller **1403** of the mobile station **1400** executes processes of receiving the propagation delay time, calculating the paging channel transmission timing, and registering it into the database in Step **1003**, similarly to the above-described Steps **201–203** of the procedure according to the first variation (Step **301–303**).

Thus, according to the second variation, detail of the process of Step **106** for the mobile station to obtain the paging channel transmission timing has been described. Transmission/reception terminating at the mobile station and the base station using thus-described procedure, and the measurement of the propagation delay in that transmission/reception are carried out accompanying an ordinary procedure, similarly to the procedure of the first variation. Accordingly, it is possible to suppress the processing load and radio resources. In particular, since the synchronizing process of hand-over branches is often carried out when a new paging channel is received, the above-described procedure that can be executed together with that process is very practical.

Next, referring to the process flow shown in FIG. **4** for a mobile station and the process flow shown in FIG. **11** for a switch, detail of the procedure of the above-mentioned Step **106** according to a third variation will be described. This procedure of the above-mentioned Step **106** according to the third variation reinforces the procedures of the first and second variations.

(1) First, in the mobile station, the controller **1403** judges if a usable communication channel has been set between the

mobile station and the switch. The procedure described here is one accompanying communication between the mobile station and the switch. When a new channel is to be set, the above-mentioned first and second variation procedures can be executed in the course of setting a new channel. Thus, the present process is executed only in a case where a communication channel has been set already (Step **400**).

(2) Next, the controller **1403** searches the paging channel transmission timing database **1404** to judge if there is a paging channel whose transmission timing has been registered, among the paging channels received this time (Step **401**).

(3) In a case where the search in Step **401** shows existence of a registered paging channel, the controller **1403** informs the switch's controller **1602** of the respective cell/sector numbers or transmission source base stations, with respect to this registered paging channel and with respect to the paging channels of unknown transmission timings (Step **402**).

(4) On the other hand, when, as a result of the search, there is not a registered paging channel, the controller **1403** informs the switch's controller **1602** of respective transmission source base station cell/sector numbers with respect to the paging channels whose transmission timings are not known (Step **403**).

(5) The switch's controller **1602** receives the paging channel transmission source base station cell/sector numbers sent from the mobile station in Steps **402** and **403**, and investigates if they include a paging channel whose transmission timing has been registered in the mobile station **1400** (Steps **1100**, **1101**).

(6) When the investigation of Step **1101** shows that satisfactory base station cell/sector numbers are contained, then, the controller **1602** searches the transmission timing difference record area **1605** of the paging channel transmission timing difference database **1604**. This search is carried out to investigate if there is registered a base station cell/sector whose transmission timing difference from the base station cell/sector in question has been recorded and whose transmission timing has not been registered in the mobile station (Steps **1102**, **1103**).

(7) When the investigation in Step **1103** shows that such a base station cell/sector has been registered, the controller **1602** records that paging channel transmission timing difference and the corresponding transmission source base station cell/sector numbers as contents of a report to the mobile station (Step **1104**).

(8) After processing of Step **1104**, or when either condition of the investigations of Steps **1101** and **1103** is not satisfied, then, the controller **1602** searches the transmission timing difference record area **1605** of the paging channel transmission timing difference database **1604** with respect to all the combinations of receiving base station cell/sectors except for already-searched ones, in order to investigate if there is an already-registered combination (Steps **1105**, **1106**).

(9) When the investigation of Step **1106** shows an already-registered combination, the controller **1602** includes the respective base station cell/sector numbers of this combination and the retrieved paging channel transmission timing difference into the contents of the report to the mobile station. Then, the controller **1602** reports the contents that have been constructed until the previous step or empty information, to the mobile station's controller **1403** (Steps **1107**, **1108**).

(10) The mobile station's controller **1403** receives the transmission timing difference information sent from the switch in the process of Step **1108**, and confirms whether there exist the report contents. As a result, when the report contents are empty information, then, the processing is ended (Steps **404**, **405**).

(11) When a transmission timing difference is included in the report contents in Step **405**, the mobile station's controller **1403** investigates whether it is a transmission timing difference between a paging channel registered in the transmission timing database **1404** and a paging channel that has not been registered (Step **406**).

(12) When the investigation in Step **406** shows that the transmission timing difference satisfies the condition, the mobile station's controller **1403** calculates the unknown transmission timing of the paging channel concerned, based on the transmission timing difference and the registered transmission timing. Then, the controller **1403** records the calculated transmission timing into the transmission timing **1410** of the database **1404** together with the base station cell number **1408** and the sector number **1409**. At that time, the switch registration information **1411** is set to "1", and the tentative registration information **1412** is not flagged (Steps **408**, **409**).

(13) When the investigation of Step **406** shows that the transmission timing difference is obtained from unregistered paging channels without satisfying the investigation condition, either one of transmission timings is decided tentatively. Then, the other transmission timing is calculated from that tentative transmission timing and the transmission timing difference. Those transmission timings are recorded into the transmission timing **1410** of the database **1404** together with respective base station cell numbers **1408** and sector numbers **1409**. At that time, any classification number that does not duplicate another number is recorded into the switch registration information **1411**, and the tentative registration information **1412** is flagged. With respect to the group of paging channels expressed by the classification number of the switch registration information **1411** and the flag of the tentative registration information **1412**, the transmission timings **1410** are rewritten into correct values when a transmission timing of some page channel belonging to that group becomes known. At that time, the switch registration information **1411** is set to "1" and the tentative registration information **1412** is unflagged (steps **407**, **409**).

With respect to the paging channel transmission timing obtained by the procedure according to the above-mentioned first or second variation, the initial value of the switch registration information **1411** of the transmission timing database **1404** is set to "0" meaning "unregistered". This is set to "1" meaning "registered", when a registration procedure is executed between the mobile station **1404** and the switch **1600** and the registration into the switch transmission timing difference database **1604** is completed. This procedure will be described below.

Thus, according to the third variation, detail of the processing of Step **106** for the mobile station to obtain the paging channel transmission timing has been described. Transmission/reception using such a procedure and terminating at the mobile station and the base station and measurement of the propagation delay in that transmission/reception are executed, first by judging whether a useable communication channel has been set between the mobile station and the switch, in Step **400**. In other words, it is assumed that this process is carried out while user data or the like is being transmitted through the communication channel. Actually, such a channel often carries out soft hand-over described in connection with the second variation procedure.

In that case, the second variation procedure is used to obtain the transmission timing with respect to the paging channel of the base station cell/sector for which hand-over branches have been set, and the third procedure is used to obtain the transmission timing or the transmission timing difference with respect to the one other paging channels. By this, it is possible to obtain as many paging channels as possible, and to improve the accuracy of obtaining the location information of the mobile station later. On the other hand, so far as such situation is concerned, since execution of the first procedure sets both the original communication channel and the communication channel used in the first procedure, the third procedure is more effective than the first procedure, in terms of use of radio resources. This becomes remarkeable when the number of communication channels that the mobile station can use at the same time is limited.

Next, the mobile station's process flow shown in FIGS. **5** and **6** will be referred to, in order to describe detail of the procedure for obtaining the paging channel propagation delay and propagation delay difference in Step **107** that has been described referring to the flowchart of FIG. **1**. First, referring to FIG. **5**, a procedure for obtaining the page channel propagation delay will be described.

(1) When the process of Step **107** is started, the mobile station's controller **1403** searches the transmission timing database **1404**, with respect to the received paging channel (Step **500**).

(2) It is investigated whether the transmission timing has been found by the search in Step **500**, and there does not exist a transmission timing, this processing is ended (Step **501**).

(3) When a transmission timing is found in the investigation of Step **501**, then, it is subtracted from the reception timing to obtain the propagation delay (Step **501**).

Here, as the transmission timing used for the above-described procedure of FIG. **5**, one for which the tentative registration information **1412** is not flagged can be used.

Next, referring to FIG. **6**, a procedure for obtaining the paging channel propagation delay difference will be described.

(1) When the process of Step **107** is started, the mobile station's controller **1403** searches the transmission timing database **1404** with respect to the received paging channel, in order to obtain as many transmission timings as possible. Here, the obtained transmission timings are ones for which the tentative registration information **1412** is not flagged. Or, even if that information is flagged, it is sufficient that the classification number of the switch registration information **1411** is same for all the transmission timings (Step **600**).

(2) Next, it is investigated whether two or more transmission timings are obtained in the process of Step **600**. If it is negated, then the processing is ended. When two or more transmission timings are obtained, any one out of the obtained paging channels is selected as a reference paging channel (Steps **601**, **602**).

(3) Next, the paging channel propagation delay difference is obtained based on the transmission/reception timing of the reference paging channel and the respective transmission/reception timings of the other paging channels. Writing the transmission timing and the reception timing of the reference paging channel as Sb and Rb, respectively, and the respective transmission and reception timings of the other paging channels as Si and Ri, then, the propagation delay differences of these paging channels can be obtained as (Ri-Rb)-(Si-Sb). Accordingly, when values of the transmission timing differences have been obtained, the transmission timings themselves can be used in relative values (Step **603**).

Next, construction of the transmission timing difference database **1604** of the switch used in the third variation procedure for obtaining the paging channel transmission timing will be described, referring to the mobile station's process flow shown in FIG. **7** and the switch's process flow shown in FIG. **12**.

(1) During a process at the starting up in each base station, the switch's controller **1602** obtains paging channel transmission timing differences between sectors within the cell of the base station from the controller **1504** of the base station, and registers those paging channel transmission differences into the database (Steps **1201**, **1202**).

(2) The mobile station's controller **1403** executes the above-described first or second variation procedure for obtaining the transmission timing during the system's operation. After the mobile station obtains the transmission timing, the switch registration information **1411** of the transmission timing database **1404** is referred to, in order to investigate whether there exists a transmission timing difference that has not been reported to the switch. When there is not an unreported transmission timing difference, then the processing is ended without doing anything (Step **700**).

(3) When the investigation of Step **700** shows an unreported transmission timing difference, then, it is investigated whether a usable communication channel has been set between the mobile station and the switch. When a usable communication channel has not been set, the processing is ended without doing anything (Step **701**).

(4) When the investigation of Step **701** shows a usable communication channel, it is investigated whether there exist two or more such channels including one whose transmission timing has been reported and thus the difference can be calculated. If there does not exist such channels, then the processing is ended without doing anything (Step **702**).

(5) When the investigation of Step **702** shows two or more channels including one whose transmission timing has been reported, then, the mobile station's controller **1403** performs the following operation, for reporting the paging channel transmission timing differences. Namely, the controller **1403** carries out classification into two cases based on whether there exist a paging channel whose transmission timing difference has been reported. When the result is affirmative, then, the one whose transmission timing difference has been reported is used as the reference paging channel. When there exist no such paging channel, then any unreported channel is selected as the reference paging channel (Steps **703–705**).

(6) Next, respective transmission timing differences between unreported paging channels and the reference paging channel are calculated, and reported to the switch, together with the corresponding transmission source base station cell/sector numbers. Here, the above-mentioned classification is carried out, since, when the transmission timing that has been already reported to the switch **1600** is including in the objects of the transmission timing difference calculation, there is a good possibility that more relations with paging channel transmission timings of cells/sectors can be recorded (Steps **706**, **707**).

(7) Next, as a result of the process of Step **707**, the switch's controller **1602** receives the report on the transmission timing differences from the mobile station, and updates the paging channel transmission timing difference database **1604**. When reports from a plurality of mobile stations are received, updating is carried out by (a) giving priority to the first report, (b) giving priority to the last report, or (c) taking an average of the reports. All the part relating to the

transmission timing difference **1605** becomes objects of updating (Steps **1203**, **1202**).

(8) Lastly, the mobile station's controller **1403** updates the switch registration information **1411** corresponding to the reported transmission timings **1410**, into the value indicating "registered" (Step **708**).

The above embodiment of the present invention has been described, in particular, taking the example in which the present invention is applied to an asynchronous CDMA mobile communication system between mobile stations and a base station. However, the present invention is not limited to this, and can be applied to a communication system that uses a communication channel whose structure is capable of setting and detecting a phase on the sending and receiving sides and through which transmissions are carried out periodically.

In the above, the present invention has been described based on the embodiments. However, the present invention is not limited to those embodiments, and can be variously modified without departing from the range of its gist, and without departing from the spirit and scope defined by the claims. The following disclose items that can/be varied as mentioned.

As described above, according to the present invention, location information of a mobile station can be obtained accompanying transmission/reception for ordinary communication control or measurement of timing. Thus, it is possible to obtain location information of a mobile station, with loads on the processing or communication traffic being suppressed and use of radio resources being decreased. Further, by using a channel through which transmissions/receptions are made periodically, it is possible to obtain the newest location information of a mobile station, in short intervals.

What is claimed is:

1. A mobile communication system comprising mobile station, a base station and a switch, wherein:

said mobile and base stations, respectively, have a controller operating at a cycle that is common to said mobile and base stations wherein a phase of the cycle is optional for each station, as a reference cycle for each of said mobile and base stations;

said controller of said base station transmits a paging channel having a same cycle as the reference cycle through an air interface, the paging channel including information indicating a transmission source;

said controller of said mobile station receives the paging channel from said base station through an air interface, obtains a phase difference between the reference cycle of said mobile station and a cycle of the paging channel at a time of receiving, as a reception timing of the received paging channel, and obtains information indicating the transmission source of the paging channel, the information being included in said paging channel; and

said controller of said mobile station transmits a communication channel to the base station, the communication channel having a same cycle as the reference cycle and having a phase whose phase difference from a reception timing of the paging channel from said base station at said mobile station becomes a reference value;

said base station has a receiver for receiving the communication channel from said mobile station;

said controller of said base station calculates a propagation delay of the paging channel and the communication channel, based on a reception timing of the communication channel at said base station, a transmission timing of the paging channel from said base station, and the reference value, and informs said mobile station of the propagation delay thus calculated; and

said controller of said mobile station calculates the transmission timing of the paging channel from said base station, based on the propagation delay received from said base station and a reception timing of the paging channel from said base station at said mobile station.

2. The mobile communication system according to claim **1**, further comprising a plurality of base stations, wherein said controller of said mobile station:

calculates a transmission timing difference between transmission timings of the paging channels from two of said base stations;

calculates a paging channel propagation delay difference, based on the transmission timing difference thus calculated and a corresponding reception timing difference; and

calculates, as information on distance from said mobile station itself to said two of said base stations, distance differences between distances from said mobile station itself to respective said two of said base stations, based on the paging channel propagation delay difference.

3. The mobile communication system according to claim **2**, wherein:

said controller of said mobile station:

selects, out of the transmission timings of the broadcast channels from said plurality of said base stations, a transmission timing of a first broadcast channel whose transmission timing difference is not informed and switch and a transmission timing of a second broadcast channel whose transmission source is different from a transmission source of said first broadcast channel;

calculates a transmission timing difference between the transmission timings thus selected; and

informs the transmission timing difference thus calculated of said switch, and wherein

said switch has a memory for storing the transmission timing difference.

4. The mobile communication system according to claim **1**, wherein:

said controller of said mobile station;

obtains information on a broadcast channel transmission timing, the broadcast channel transmission timing being a phase difference between the reference cycle of said mobile station itself and a cycle of the broadcast channel of the base station at a time of transmission;

has a memory for storing the information on the broadcast channel transmission timing together with information indicating a transmission source of the broadcast channel;

calculates information on a propagation delay of the broadcast channel, based on information on a reception timing and the transmission timing of the broadcast channel, when said controller of said mobile station receives a broadcast channel for which information on a transmission timing is retained in advance, or newly obtains information on a transmission timing of a received broadcast channel; and

calculates information on a distance between said mobile station itself and said base station, based on the information on the propagation delay of the broadcast

channel and the information indicating the transmission source of the broadcast channel.

5. A mobile station configured to calculate its own location from a base station used in a mobile communication system employing a mobile station, a base station, and a switch, said mobile station comprising:

a controller operating at a reference cycle, said reference cycle being a cycle common to said base station although a phase of said cycle is optional, and wherein said controller of said mobile station;further configured to,

define, as a reference timing, an actual reception timing of a paging channel at said mobile station itself, the paging channel specifying said base station and being transmitted in accordance with a reference cycle of said base station;

control said mobile station itself such that a communication channel is transmitted to said base station after a known phase difference from the reference timing;

receive data on a propagation delay between said base station and the mobile station itself, the propagation delay being calculated by said base station on receiving the communication channel from said mobile station; and

calculate a transmission timing of the paging channel from said base station, based on the data on the propagation delay thus received and the reference timing.

6. The mobile station according to claim **5**, wherein:

said controller calculates information on a distance between said mobile station itself and said base station, based on the information on the propagation delay of the broadcast channel and the information indicating the transmission source of the broadcast channel.

7. The mobile station according to claim **6**, wherein:

said controller receives paging channels from a plurality of said base stations, and calculates the location of said mobile station itself, based on respective distances from said base stations.

8. A base station that is used in a mobile communication system having a mobile station, a base station, and a switch, and that calculates a distance from a mobile station, said base station comprising:

a transmitter configured to transmit, as a paging channel, information for specifying said base station itself for communicating with said mobile station within a communication area of said base station and information for specifying a communication channel transmission timing of said mobile station; and

a receiver configured to receive the information channel from said mobile station that has received the paging channel; calculates a propagation delay, based on a reception timing of receiving the communication channel, a transmission timing of the paging channel, and a transmission timing of the communication channel of said mobile station: and informs said mobile station of this calculated propagation delay.

9. The base station according to claim **8**, wherein:

the information for specifying the communication channel transmission timing expresses a constant timing from a reception timing of said mobile station for receiving a paging channel from said base station until transmission of the communication channel.

* * * * *

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(54) METHOD AND SYSTEM FOR CALIBRATING ANTENNA TOWERS TO REDUCE CELL INTERFERENCE

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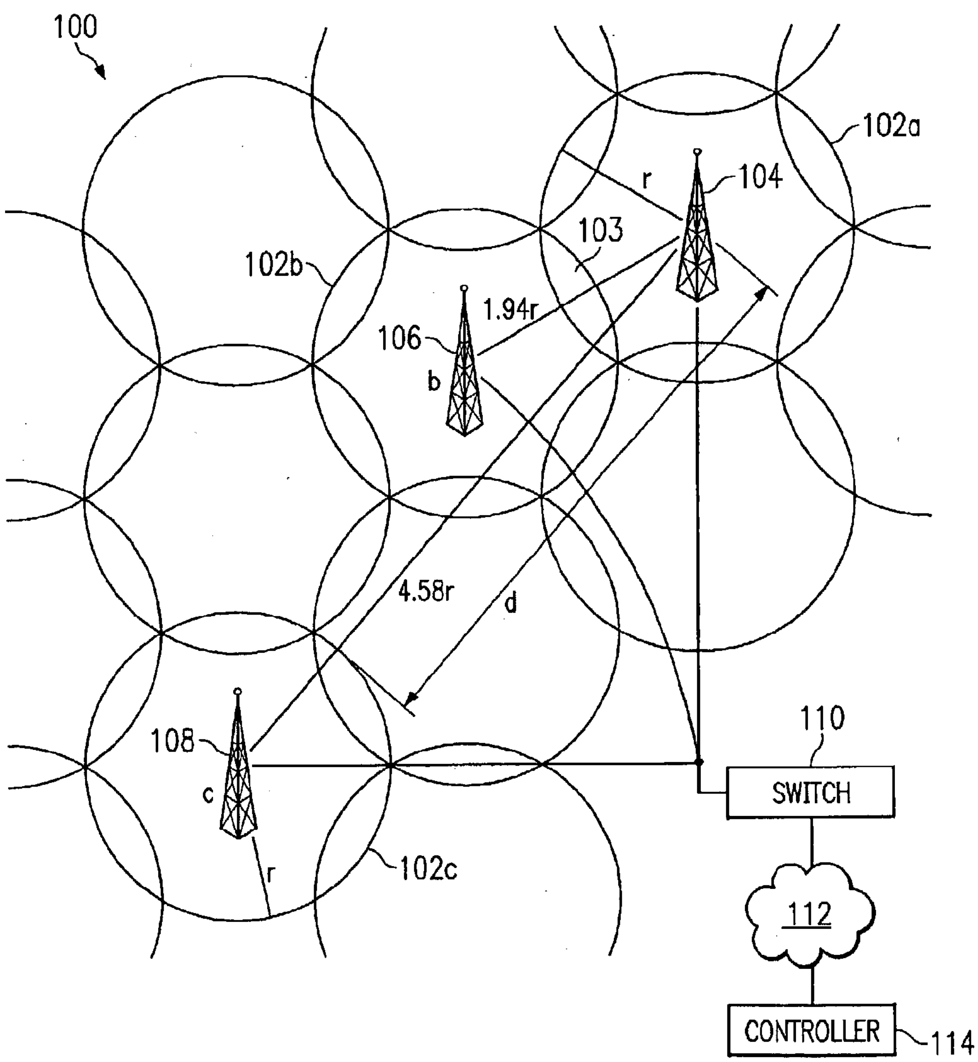
(52) **U.S. Cl.** **455/562**; 455/561

(57) **ABSTRACT**

An antenna tower receives a first calibration signal and a second calibration signal. The antenna tower determines an adjustment angle from the first calibration signal and the second calibration signal, and uses the adjustment angle to adjust a subscriber beam in elevation to reduce cell site interference.



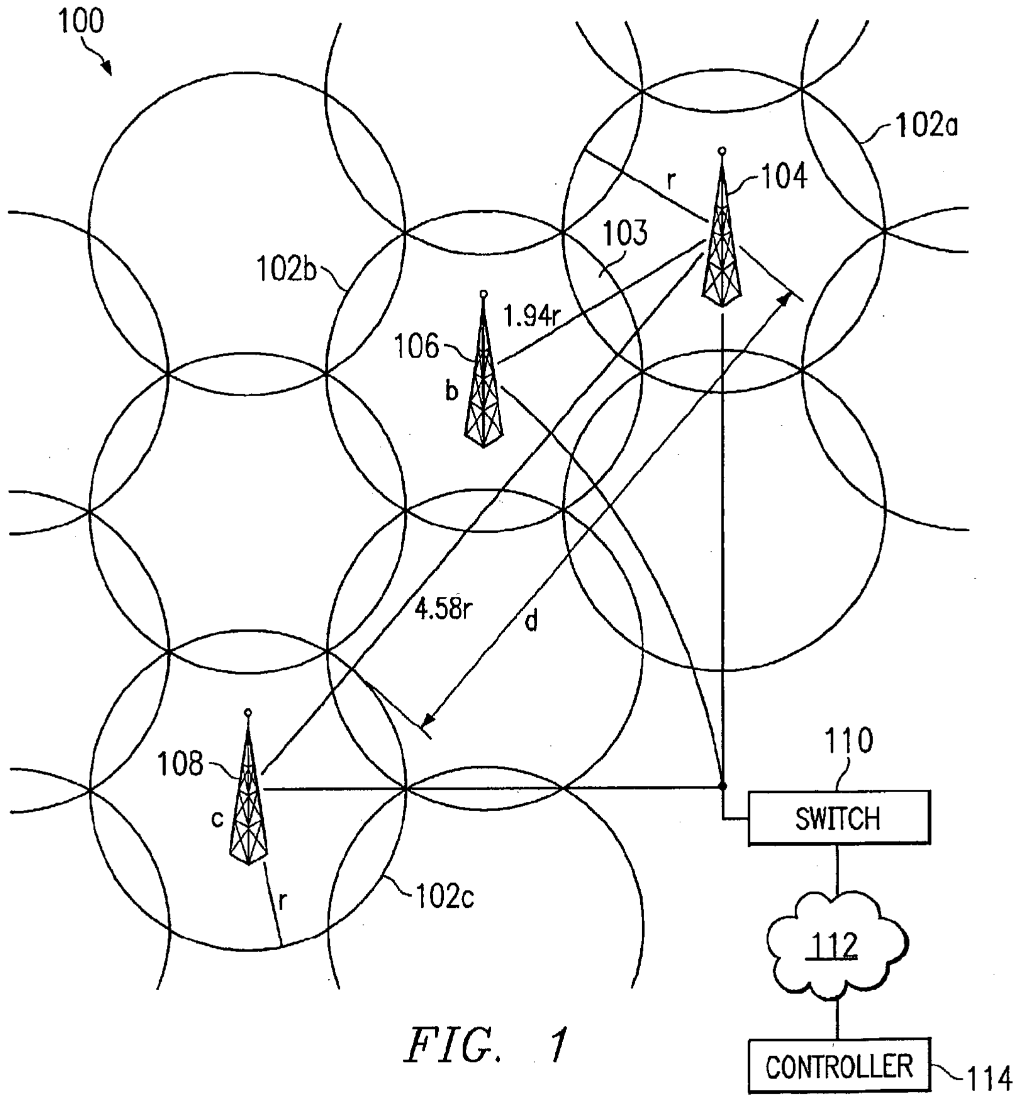

100
102a
r
104
103
102b
1.94r
106
b
4.58r
d
108
c
r
102c
110
SWITCH
112
CONTROLLER
114

FIG. 1

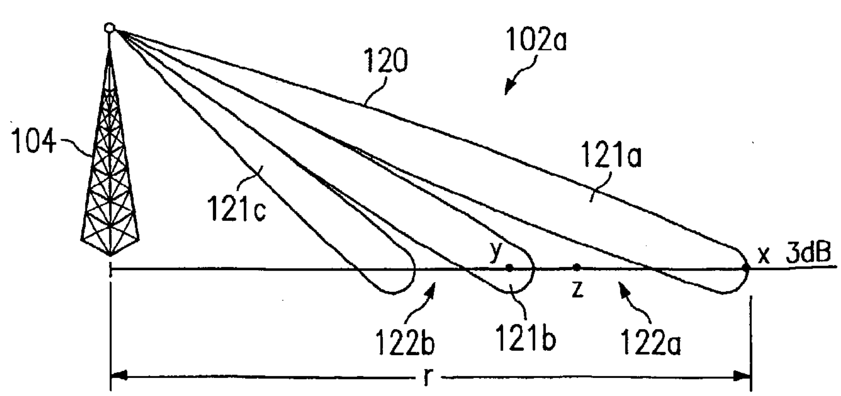

120
102a
104
121a
121c
y
x 3dB
z
122b
121b
122a
r

FIG. 2

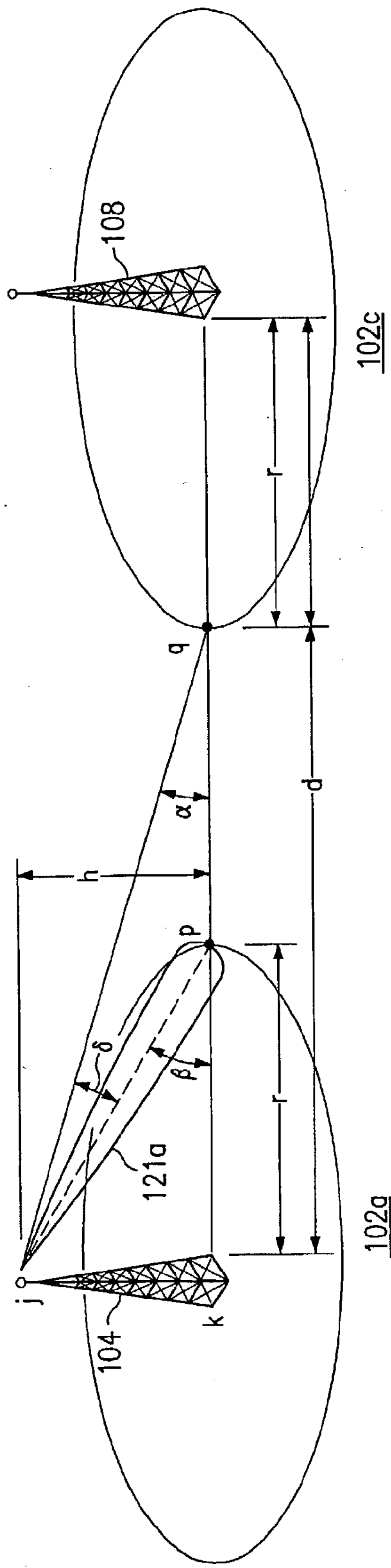

108
102c
r
d
q
α
h
p
δ
β
121a
r
102a
j
104
k

FIG. 3

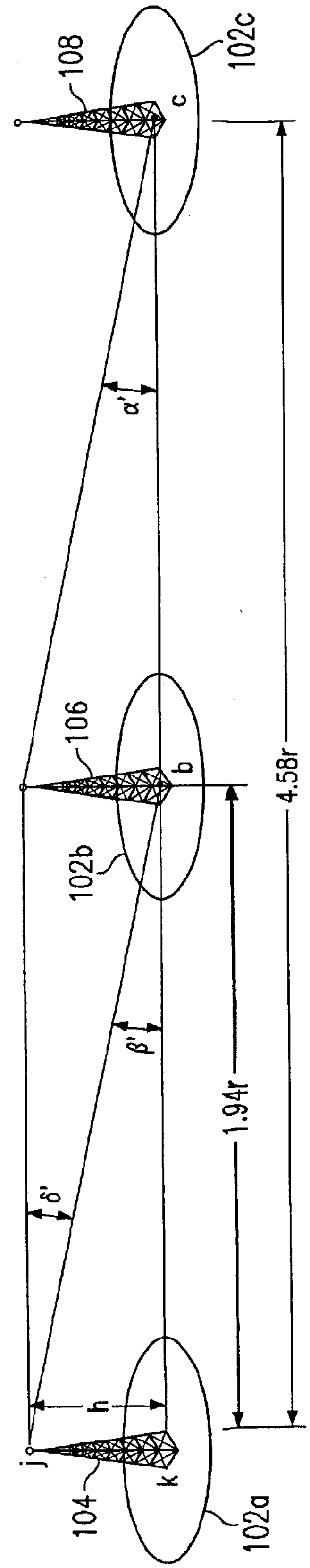

108
102c
c
α'
106
b
102b
4.58r
β'
1.94r
δ'
h
j
104
k
102a

FIG. 4

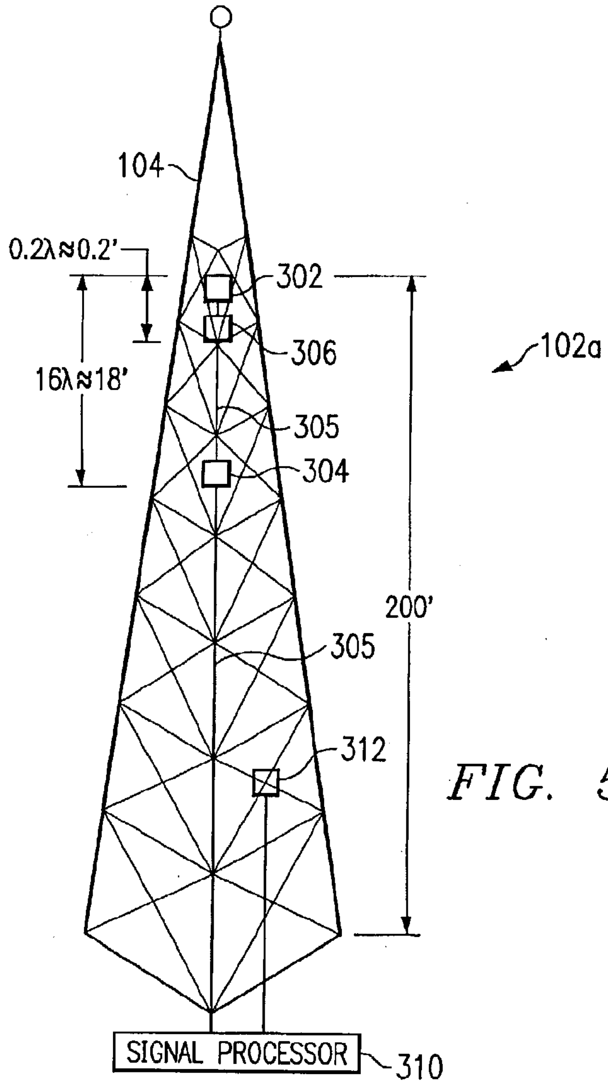

104
0.2λ≈0.2'
302
306
16λ≈18'
102a
305
304
200'
305
312
SIGNAL PROCESSOR
310

FIG. 5

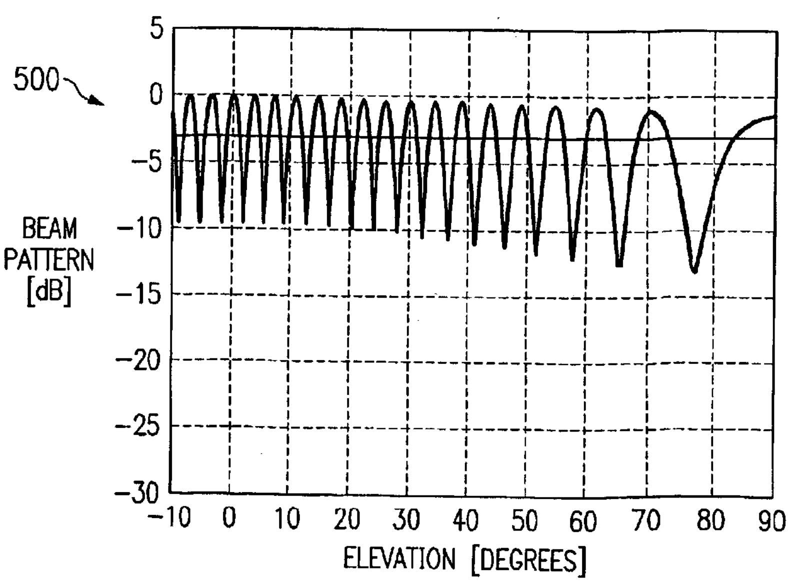

500
5
0
-5
BEAM PATTERN [dB]
-10
-15
-20
-25
-30
-10 0 10 20 30 40 50 60 70 80 90
ELEVATION [DEGREES]

FIG. 6

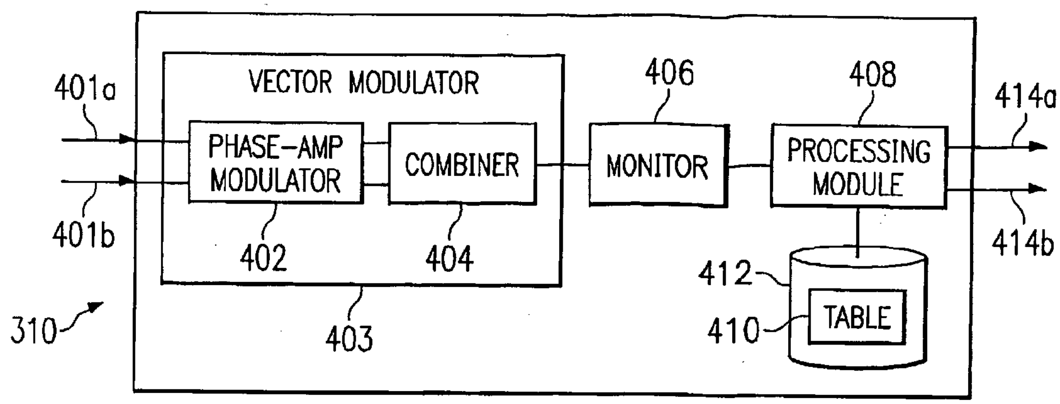


FIG. 7

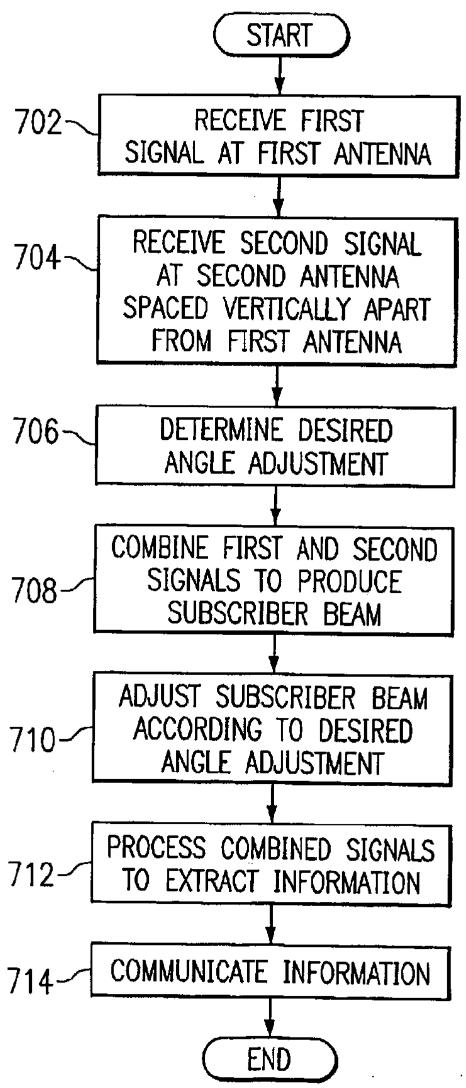


FIG. 8

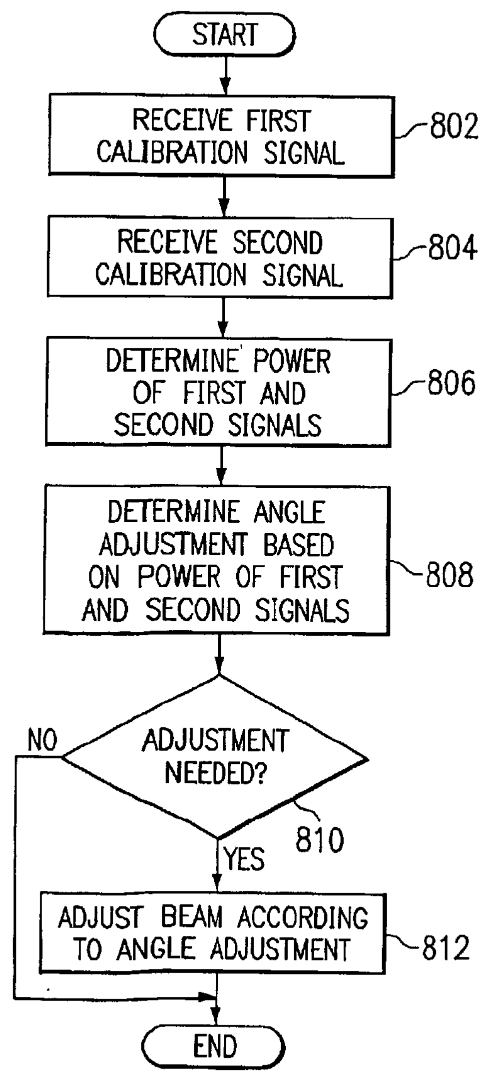


FIG. 9

METHOD AND SYSTEM FOR CALIBRATING ANTENNA TOWERS TO REDUCE CELL INTERFERENCE

TECHNICAL FIELD OF THE INVENTION

[0001] This invention relates generally to the field of communications systems and more specifically to a method and system for calibrating antenna towers to reduce cell interference.

BACKGROUND OF THE INVENTION

[0002] The rising use of communications systems has led to the increasing demand for more effective and efficient techniques for communicating signals. An antenna tower located in a cell site communicates a signal to a subscriber in the cell site. Signals from other antenna towers, however, may interfere with the communicated signal, resulting in degraded communication. Known methods for reducing cell site interference involve using a tall antenna tower to point a signal down to the subscriber. The angle at which the signal is pointed reduces cell site interference. These methods, however, are impractical because they require relatively tall antennas.

SUMMARY OF THE INVENTION

[0003] In accordance with the present invention, a method and system for communicating signals are provided that substantially eliminate or reduce the disadvantages and problems associated with previously developed systems and methods. In general, the present invention reduces cell interference.

[0004] According to one embodiment, a system for communicating signals is disclosed that includes a cell site. An antenna tower is located at the cell site and receives a first calibration signal from a first location and a second calibration signal from a second location. The antenna tower determines an adjustment angle from the first calibration signal and the second calibration signal, and uses the adjustment angle to adjust a subscriber beam in elevation to reduce cell site interference.

[0005] According to another embodiment, a method for communicating signals is disclosed. A first calibration signal is received from a first location. A second calibration signal is received from a second location. An adjustment angle is determined from the first calibration signal and the second calibration signal. A subscriber beam is adjusted in elevation to reduce cell site interference using the adjustment angle.

[0006] According to still another embodiment, a system for communicating signals is disclosed. A first antenna tower transmits a first calibration signal. A second antenna tower transmits a second calibration signal. A target antenna tower receives the first calibration signal and the second calibration signal. The target antenna tower determines an adjustment angle from the first calibration signal and the second calibration signal, and uses the adjustment angle to adjust a subscriber beam in elevation to reduce cell site interference.

[0007] A technical advantage of the communication system is that the system reduces cell interference, thus improving the quality of communication. The communication system adjusts a subscriber beam in elevation in order to avoid cell interference. The communication system includes vertically spaced apart antennas that allow for precise adjustment of the subscriber beam in elevation to avoid interfering signals from other cells. Additional antennas may be used to reduce the nulls of the beam pattern generated by the antennas. The communication system may periodically calibrate the direction of the subscriber beam in order to properly adjust the subscriber beam to avoid cell interference.

[0008] Other technical advantages are readily apparent to one skilled in the art from the following figures, descriptions, and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] For a more complete understanding of the present invention and for further features and advantages, reference is now made to the following description, taken in conjunction with the accompanying drawings, in which:

[0010] **FIG. 1** illustrates one embodiment of a communication system incorporating the present invention;

[0011] **FIG. 2** illustrates a cell site and its associated subscriber beam in the communication system;

[0012] **FIG. 3** illustrates cell sites in the communication system;

[0013] **FIG. 4** illustrates cell sites in the communication system;

[0014] **FIG. 5** is a schematic diagram of one embodiment of a cell site in the communication system;

[0015] **FIG. 6** illustrates a beam pattern generated by the cell site;

[0016] **FIG. 7** is a block diagram of one embodiment of a signal processor for the cell site;

[0017] **FIG. 8** is a flowchart illustrating a method for communicating signals in the communication system; and

[0018] **FIG. 9** is a flowchart illustrating a method for calibrating signals in the communication system.

DETAILED DESCRIPTION OF THE DRAWINGS

[0019] **FIG. 1** illustrates one embodiment of a communication system **100** that covers a contiguous area that is broken down into a series of overlapping cell sites, or cells, for example, cell sites **102***a-c*. According to one embodiment, each cell site **102***a-c* is surrounded by six adjacent cell sites. Other cell site patterns may be used without departing from the invention. In this particular embodiment, cell sites **102***a-c* are approximately the same size, and each cell site **102***a-c* is approximately circular with a radius r. Each cell site **102***a-c* has an antenna tower **104**, **106**, and **108**, respectively, located at approximately the center of the cell site. Antenna tower **106** is located at point b of cell site **102***b*, and antenna tower **108** is located at point c of cell site **102***c*.

[0020] In one embodiment, antenna towers **104**, **106**, and **108** transmit signals to and receive signals from a subscriber's wireless device, for example, a cell phone, data phone, data device, portable computer, or any other suitable device capable of communicating information over a wireless link. Each antenna tower **104**, **106**, and **108** is responsible for communicating signals within its own cell site **102***a-c*, respectively. Each antenna tower **104**, **106**, and **108** gener-

ates a subscriber beam with which a subscriber within the cell site may communicate with the tower. For this particular arrangement of cells, the distance between antenna towers **104** and **106** is approximately 1.94 r, and the distance between antenna towers **104** and **108** is approximately 4.58 r.

[0021] The antennas of antenna towers **104**, **106**, and **108** communicate signals at specific wavelengths or frequencies. Communication system **100** may employ a frequency reuse plan to reduce cell interference. However, if one antenna is too close to another antenna tower operating at the same frequency, cell site interference may result. Cell site interference may result from the interaction of signals from more than one antenna tower, which may result in the degradation of the signals.

[0022] In a particular embodiment, antenna tower **106** and antenna tower **104** may operate at different frequencies to reduce or effectively eliminate interference. Due to the limited bandwidth available for a frequency reuse plan, antenna towers **104** and **108** may share the same frequencies in communication system **10**. Other reuse patterns may be used without departing from the invention. However, if antenna tower **104** communicates strong signals outside a radius of d, where d is the distance from antenna tower **104** to the closest edge of cell site **102***c*, cell site interference may result. This cell interference between cell sites operating at similar frequencies may be particularly troublesome for systems in hilly or mountainous terrain, for systems having a limited frequency reuse plan or bandwidth, and for systems employing higher power communications to support greater data communication bandwidth.

[0023] In one embodiment, one or more switches, access devices, or other suitable equipment (referred to generally as switch **110**) coordinates and controls communications among a communication network **112** and antenna towers **104**, **106**, and **108**. Communication network **112** may be a satellite, microwave, or other suitable wireline or wireless network, or a combination of the preceding. In a particular embodiment, switch **110** couples towers **104**-**108** to the public switch telephone network (PSTN). A network controller **114** controls and maintains communications network **112**.

[0024] In operation, antenna tower **104** communicates signals to a subscriber in cell site **102***a* by generating a subscriber beam. Antenna tower **104** is required to communicate signals within a radius r, but the signals need to diminish outside of a radius d. If antenna tower **104** communicates strong signals outside of radius d, cell site interference may result between antenna tower **104** and antenna tower **108**, which operates at the same frequency. To communicate with a subscriber in cell site **102***a*, antenna tower **104** generates a subscriber beam and adjusts the subscriber beam in elevation to reduce interference with cell site **102***c*, thus improving signal communication.

[0025] **FIG. 2** illustrates a simplified diagram of a cell site **102***a* and its associated beam pattern **120** for communicating signals. **FIG. 2** exaggerates the relative magnitude between the radius r of cell site **102***a* and the height of antenna tower **104** to illustrate the elevation adjustment concept. Antenna tower **104** generates beam pattern **120** that includes subscriber beams **121***a*-*c*. Beam **121***a* services a subscriber at point x located at the edge of cell site **102***a*, approximately a distance r from antenna tower **104**. In order to service subscribers in cell site **102***a* while reducing interference with other cells, beam **121***a* may be directed in elevation to place its upper 3 dB dropoff gain at point x. The peak of beam **121***a* is the decibel measure of the antenna gain, and may be, for example, approximately 23 dB. Therefore, the gain provided at point x in this example would be approximately 20 dB. A subscriber at point y may be serviced by beam **121***b*.

[0026] Nulls **122***a*-*b* are local minimums of beam pattern **120** between subscriber beams **121***a*-*c*, where beam pattern **120** experiences reduced gain. For example, subscriber beam **120** may not be able to service a subscriber located at point z of null **122***a*. Antenna tower **104** may use an antenna system discussed in more detail in connection with **FIGS. 5 and 6** in order to reduce or truncate nulls **122***a*-*b* to provide continuous subscriber coverage at all distances from antenna tower **104**.

[0027] **FIG. 3** illustrates in more detail cell sites **102***a* and **102***c* with antenna towers **104** and **108**, respectively, that operate at the same frequency. **FIG. 3** exaggerates the relative magnitude between the radii of cell sites **102***a* and **102***c* and the heights of antenna towers **104** and **108** to illustrate the elevation adjustment concept. To avoid interference from signals from antenna tower **108**, antenna tower **104** adjusts subscriber beam **121***a* in elevation to avoid signals from cell site **102***c*. The precision with which subscriber beam **121***a* should be adjusted may be computed from the height h of antenna tower **104** and distances d and r. In this embodiment, point p is the point at the edge of cell site **102***a* closest to antenna tower **108**, and point q is the point at the edge of cell site **102***c* closest to antenna tower **104**. Height h is the distance between point k and point j, r is the radius of cell sites **102***a* and **102***c*, and d is the distance between point k and point q. Antenna tower **104** broadcasts signals within radius r, but the signals need to diminish outside of radius d.

[0028] Angle α is the angle between the line from point j to point q and the line from point q to point k. Angle β is the angle between the line from point j to point p and the line from point p to point k. Angle δ is the angle between the line from point p to point j and the line from point j to point q. Angle δ may be used to determine the vertical precision needed to adjust subscriber beam **121***a* such that the beam **121***a* illuminates the area within radius r, but diminishes outside of radius d.

[0029] In one embodiment, height h of antenna tower **104** is two hundred feet, radius r of cell site **108** is five miles, and the distance d is twenty miles. If:

$$\tan\alpha = h/d, \text{ and}$$
$$\tan\beta = h/r, \text{ then}$$
$$\alpha = 0.11^\circ$$
$$\beta = 0.43^\circ$$
$$\delta = \beta - \alpha = 0.32^\circ$$

[0030] That is, subscriber beam **121***a* may need to be adjusted with a vertical precision of at least, for example, $\delta/5=0.064^\circ$. More or less precision may be required in some situations, for example, at least $\delta/10=0.032^\circ$ or $\delta/2=0.16^\circ$. A

tall antenna tower may be used to precisely adjust a subscriber beam. Such an antenna tower, however, may be impracticably large. Antenna tower **104** may precisely adjust a subscriber beam using a more practical antenna system discussed in more detail in connection with **FIGS. 4 and 6**.

[**0031**] According to one embodiment, antenna tower **104** calibrates subscriber beam **121***a* to compensate for the terrain and environment around antenna tower **104**. Changes in the equipment resulting from, for example, environmental changes, may alter the direction of subscriber beam **121***a*, thus antenna tower **104** periodically calibrates subscriber beam **121***a* to adjust the direction of subscriber beam **121***a*. To calibrate subscriber beam **121***a*, ideally measurements at radius r and distance d may be taken. Calibration transmitters placed at radius r and distance d could emit calibration signals. Antenna tower **104** would then receive the calibration signals to determine the direction of the subscriber beam **121***a* and then adjust subscriber beam **121***a* in elevation accordingly.

[**0032**] Placing transmitters at radius r and distance d, however, may be impractical, because in general communication devices are not located at these locations. To estimate calibration measurements, calibration transmitters may be placed at antennas near radius r and distance d. Referring to **FIG. 1**, for example, instead of placing calibration transmitters at the edge of cell sites **102***a* and **102***c*, transmitters may be placed at antenna towers **106** and **108**. Transmitters placed at antenna towers **106** and **108** yield approximations of measurements resulting from transmitters placed at radius r and distance d.

[**0033**] **FIG. 4** illustrates cell sites **102***a*, **102***b*, and **102***c* with antenna towers **104, 106**, and **108**, respectively. **FIG. 4** exaggerates the relative magnitude between the radii of cell sites **102***a* and **102***c* and the heights of antenna towers **104** and **108** to illustrate the elevation adjustment concept. Placing the calibration transmitters at antenna towers **106** and **108**, however, requires more stringent beam width and pointing requirements. In the particular cell site scheme illustrated in **FIG. 1**, calibration transmitters are placed at point b at antenna tower **106** located 1.94 r miles away from antenna tower **104**, and at point c at antenna tower **108** located 4.58 r away from antenna tower **104**. Angle α' is the angle between the line from point j to point c and the line from point c to point k. Angle β' is the angle between the line from point j to point b and the line from point b to point k. Angle δ' is the angle between the line from point b to point j and the line from point j to point c. If radius r is five miles, and h is 200 feet, then:

$$\alpha' = 0.22°$$
$$\beta' = 0.09°, \text{ and}$$
$$\delta' = 0.13°$$

[**0034**] That is, subscriber beam **121***a* may need to be adjusted with a vertical precision of, for example, at least $\delta'/5=0.026°$. More or less precision may be needed in some situations, for example, at least $\delta'/10-0.013°$ or $\delta'/2-0.065°$. An antenna tower for generating such a subscriber beam is discussed in more detail in connection with **FIGS. 5 and 6**.

[**0035**] **FIG. 5** is a schematic diagram of one embodiment of a cell site **102***a* in the communication system that includes an antenna tower **104** for communicating signals. According to one embodiment, antenna tower **104** may be approximately two hundred feet high. Antenna tower **104** includes antennas **302** and **304** that operate at a specific wavelength and frequency to form a subscriber beam. Antennas **302** and **304** may be, for example, sixteen dipole 4×4 array antennas operating at a frequency of approximately 900 MHz and a wavelength of approximately 1.1 feet, and may be substantially vertically separated from each other by, for example, sixteen wavelengths. Antennas **302** and **304** are coupled to a signal processor **310** by, for example, a low loss coaxial cable **305**. By using two antennas **302** and **304** vertically separated, antenna tower **104** generates a narrow subscriber beam that may be precisely pointed to avoid cell site interference, resulting in improved signal communication without requiring an impracticably tall antenna.

[**0036**] A third antenna **306**, or more antennas, may be used to reduce the nulls between lobes in the subscriber beam. Antenna **306** may be placed relatively close to antenna **302**, for example, less than one wavelength, for example, 0.2 wavelengths, away from antenna **302**. Antenna **306** may also be coupled to signal processor **310** using coaxial cable **305**. Third antenna **306** reduces the nulls of the beam pattern, as shown in **FIG. 6**. Reducing the nulls of the beam pattern allows for greater coverage of all site **102***a*, such that more subscribers may be serviced.

[**0037**] **FIG. 6** illustrates one embodiment of a beam pattern **320** generated by cell site **102***a* having three vertically placed antennas **302, 304**, and **306**. First antenna **302** and second antenna **304** are approximately sixteen wavelengths apart, and third antenna **306** is approximately 0.2 wavelengths from first antenna **302**. Beam pattern **320** exhibits reduced nulls, since the subscriber beam generates a signal (at least approximately the peak of the beam minus 10 dB) at all elevations. By using third antenna **306**, antenna tower **104** reduces the nulls of the subscriber beam, resulting in more coverage for the cell site, thus improving signal communication.

[**0038**] Referring back to **FIG. 5**, antenna tower **104** may also include a transmitter **312** coupled to signal processor **310** that transmits a calibration signal. The calibration signal is used by antenna towers at other cell sites to calibrate their own subscriber beams.

[**0039**] In operation, antennas **302, 304**, and **306** generate a subscriber beam to service cell site **102***a*. Signal processor **310** adjusts the subscriber beam in elevation to reduce cell site interference, resulting in improved signal communication. Antennas **302, 304**, and **306**, receive calibration signals, and transmit the signals to signal processor **310**. Signal processor **310** determines an adjustment angle in response to the calibration signals, and then calibrates the subscriber beam using the adjustment angle, ensuring the high quality of signal communication. Transmitter **312** transmits a calibration signal used by antenna towers at other cell sites to calibrate their own subscriber beams.

[**0040**] **FIG. 7** is a block diagram of one embodiment of a signal processor **310** for communicating signals. According to one embodiment, signal processor receives calibration signals, determines an adjustment angle, and adjusts a subscriber beam using the adjustment angle. Signal processor **310** includes a vector modulator **403**, which in turn includes a phase-amplitude modulator **402** and a signal

combiner **404**. Vector modulator **403** receives input signals **401***a-b* from antennas **302** and **304**, respectively. Phase-amplitude modulator **402** modulates the phase and amplitude of signals **401***a-b* in order to combine signals **402***a-b*. An array of attenuators may be used to vary amplitude, and switch delay lines may be used to vary phase. Alternatively, the signal may be divided into I/Q components. I/Q components may be controlled using attenuators, and I/Q components may be combined to vary phase shifting. Other suitable means of modulating the phase and amplitude of the signals may be used. Signal combiner **404** combines signals **401***a-b* using cancellation and/or enhancement techniques. Cancellation procedures attempt to reduce the noise of the combined signals, and enhancement procedures attempt to enhance the data of the combined signals. Any other suitable procedure to combine signals **401***a-b* may be used.

[0041] In one embodiment, signal processor **310** also includes a monitor **406** and a processing module **408**. Monitor **406** receives the combined signals from signal combiner **404**. Monitor **406** monitors the power of the combined signals and transmits the measurement of the power to processing module **408**. Processing module **408** uses the information to construct a beam pattern of the subscriber beam **121***a*. Using the beam pattern, processing module **408** determines an adjustment angle of the beam in order to calibrate the beam. Processing module **408** may use a lookup table **410** located in a memory **412** to determine the adjustment angle from the beam pattern.

[0042] TABLE 1 illustrates one embodiment of lookup table **410**.

TABLE 1

	First Signal x (dB)	Second Signal y (dB)	Angle Adjustment (°)
1	$0 \leq x < 1$	$0 \leq y < 1$	−0.05
2	$0 \leq x < 1$	$1 \leq y < 2$	−0.10
3	$0 \leq x < 1$	$y \geq 2$	−0.15
4	$1 \leq x < 2$	$0 \leq y < 1$	0
5	$1 \leq x < 2$	$1 \leq y < 2$	−0.05
6	$1 \leq x < 2$	$y \geq 2$	−0.10
7	$x \geq 2$	$0 \leq y < 1$	+0.05
8	$x \geq 2$	$1 \leq y < 2$	0
9	$x \geq 2$	$y \geq 2$	−0.05

[0043] The first and second columns of TABLE 1 show the measurements of the first and second calibration signals, respectively. For example, first and second calibration signals are received from antenna towers **106** and **108**, respectively. The third column shows the angle by which the subscriber beam needs to be adjusted based on the measurements. A positive angle adjustment indicates an upward adjustment, a negative angle adjustment indicates a downward adjustment, and a zero angle adjustment indicates no adjustment.

[0044] In this embodiment, the first calibration signal is stronger than the second calibration signal when subscriber beam **121***a* is properly calibrated, that is, when subscriber beam **121***a* is pointing in the desired direction. For example, line 4 of TABLE 1 indicates that if the strength of the first signal is greater than or equal to 1 dB and less than 2 dB and if the strength of the second signal is greater than or equal to 0 dB and less than 1 dB, then no angle adjustment is needed. Similarly, line 8 indicates that if the strength of the first signal is greater than or equal to 2 dB and if the strength of the second signal is greater than or equal to 1 dB and less than 2 dB, then no angle adjustment is needed.

[0045] If the first calibration signal is not strong enough, subscriber beam **121***a* needs to be pointed downward, as indicated by a negative angle adjustment. For example, in lines 1, 2, 3, 5, 6, and 9, the strength of the first calibration signal is not sufficiently greater than the strength of the second calibration signal, and TABLE 1 indicates that a negative angle adjustment is needed. If the first calibration signal is too strong, TABLE 1 indicates than that an upward adjustment of subscriber beam **121***a* is needed. For example, in line 7, the first calibration signal is too strong, and TABLE 1 indicates that a positive angle adjustment is needed.

[0046] Table **410** may be determined from the initial calibration of antenna tower **104**. During the initial calibration, the position of subscriber beam **121***a* is measured, and the power of a first and a second calibration signal is determined by antenna **104**. Repeated measurements of the position of subscriber beam **121***a* are associated with determinations of the power of the corresponding calibration signals to form table **410**. Although shown using a lookup table based on calibration ranges, processing module **408** may use other empirical, algorithmic, or other suitable technique to generate an adjustment angle based on calibration signals.

[0047] Processing module **408** uses the adjustment angle to generate output signals **414***a-b*. Signals **414***a-b* form a subscriber beam that is calibrated in elevation to avoid cell site interference. Signal processor **401** provides fast, effective calibration of the subscriber beam, resulting in reduced signal interference and improved signal communication.

[0048] **FIG. 8** is a flowchart describing a method for communicating signals in the communication system. Antenna tower **104** of cell site **102***a* generates a subscriber beam **121***a* and adjusts the subscriber beam **121***a* in elevation in order to reduce cell site interference.

[0049] The method begins at step **702**, where antenna **302** receives a first signal. Antenna **302** is part of antenna tower **104**. Antenna **304** of antenna tower **104** receives a second signal at step **704**. Antenna **304** is spaced vertically apart from antenna **302**. Signal processor determines a desired angle adjustment at step **706**. One possible angle adjustment is described in more detail in connection with **FIG. 9**. Other suitable techniques of angle adjustment, for example, open loop adjustment, absolute adjustment, may be used. Antenna tower **104** generates subscriber beam **121***a* of beam pattern **120** at step **708**. Antennas **302**, **304**, and **306** communicate signals that combine to form subscriber beam **121***a*. The signals from antennas **302** and **304** combine to form beam pattern **120** with narrow pencil beams, and the signal from antenna **306** reduces the nulls of beam pattern **120**. Antenna tower **104** adjusts the subscriber beam at step **710** according to the angle adjustment.

[0050] Processing module **408** uses the adjustment angle to generate output signals **414***a-b* that form subscriber beam **121***a* that is calibrated in elevation to point in a desired direction, reducing cell site interference and improving signal communication. The received signals are combined, and information is extracted from the signals, at step **712**. The received signals are transmitted to signal processor **310**.

Combiner **404** of signal processor **310** combines the signals, and processing module **408** extracts information from the signals. Signal processor **310** communicates the information at step **714**. Signal processor **310** transmits the information to switch **110**, which transmits the information to network **112**. After signal processor **310** transmits the information, the method terminates.

[**0051**] **FIG. 9** is a flowchart illustrating a method for calibrating signals in the communication system. According to one embodiment, antenna tower **104** receives calibration signals from antenna towers **106** and **108**, determines an adjustment angle from the calibration signals, and calibrates subscriber beam **121***a* using the adjustment angle.

[**0052**] The method begins at step **802**, where antenna tower **104** of cell site **102***a* receives a first calibration signal. Antenna tower **106** of cell site **102***b* transmits a calibration signal to antenna tower **104**. The calibration signal from antenna tower **106** approximates a calibration signal sent from the edge of cell site **102***a*, the radius within which antenna tower **104** is required to transmit signals. Antenna tower **104** receives a second calibration signal at step **804**. Antenna tower **108** of cell site **102***c* transmits the second calibration signal to antenna tower **104**. The calibration signal from antenna tower **108** approximates a calibration signal sent from radius d, the radius beyond which antenna tower **104** is restricted from broadcasting strong signals.

[**0053**] Antenna tower **104** determines the power of the first and second calibration signals at step **806**. The calibration signals are transmitted to signal processor **310**. Signal processor **310** includes vector modulator **403**, monitor **406**, processing module **408**, and lookup table **410**. Vector modulator **403** adjusts the phases and amplitudes of calibration signals, and then combines the calibration signals. Monitor **406** measures the power of the combined calibration signals. Processing module **408** generates beam pattern **120** from the power to determine the direction of subscriber beam **121***a*. From the direction of subscriber beam **121***a*, processing module **408** determines an adjustment angle needed to point subscriber beam **121***a* in a desired direction, at step **808**. Processing module uses table **410** to determine the adjustment angle, as described in connection with **FIG. 7**.

[**0054**] Antenna tower **104** determines whether an angle adjustment is needed at step **810**. If an angle adjustment is not needed, the method terminates. If an angle adjustment is needed, the method proceeds to step **812**. Antenna tower **104** calculates the antenna signals that generate subscriber beam **121***a* pointing in the desired direction, and adjusts subscriber beam **121***a* accordingly. Antenna tower generates subscriber beam **121***a* pointing in the desired direction to reduce cell site interference, resulting in improved signal communication, and the method terminates.

[**0055**] Although an embodiment of the invention and its advantages are described in detail, a person skilled in the art could make various alternations, additions, and omissions without departing from the spirit and scope of the present invention as defined by the appended claims.

What is claimed is:

1. A system for communicating signals, the system comprising:

a cell site;

an antenna tower located at the cell site and operable to receive a first calibration signal from a first location and a second calibration signal from a second location, to determine an adjustment angle from the first calibration signal and the second calibration signal, and to adjust a subscriber beam in elevation to reduce cell site interference using the adjustment angle.

2. The system of claim 1, wherein the antenna tower adjusts the subscriber beam with a precision of at least one-half of one degree.

3. The system of claim 1, wherein:

the cell site has a radius; and

a subscriber at the approximate radius receives the subscriber beam at approximately three decibels lower than a peak of the subscriber beam.

4. The system of claim 1, wherein:

the antenna tower comprises a first antenna and a second antenna spaced apart from the first antenna in a substantially vertical direction; and

the first antenna and the second antenna are operable to receive the first calibration signal and the second calibration signal and to generate the subscriber beam.

5. The system of claim 4, wherein:

the antenna tower operates at a wavelength; and

the distance between the first antenna and the second antenna is greater than ten wavelengths.

6. The system of claim 4, further comprising a signal processor operable to receive the first calibration signal and the second calibration signal from the first antenna and the second antenna and to generate the adjustment angle.

7. The system of claim 4, wherein:

the antenna tower comprises a third antenna;

the first antenna, the second antenna, and the third antenna are operable to receive the first calibration signal and the second calibration signal and to generate the subscriber beam; and

the third antenna is operable to reduce a null of the subscriber beam.

8. The system of claim 7, wherein:

the antenna tower operates at a wavelength; and

the distance between the second antenna and the third antenna is less than one wavelength.

9. The system of claim 1, wherein:

the cell site is a target cell site;

the antenna tower is a target antenna tower and operates at a frequency;

the first location comprises a first antenna tower servicing a first cell site adjacent to the target cell site; and

the second location comprises a second antenna tower operating at the same frequency as the target antenna tower.

10. The system of claim 1, wherein:

the cell site has a radius;

the distance between the antenna tower and the first location is approximately two times the radius; and

the distance between the antenna tower and the second location is approximately four and one-half times the radius.

11. The system of claim 1, wherein:

the antenna tower comprises a monitor operable to monitor the power of the first calibration signal and the second calibration signal; and

the antenna tower is operable to determine the adjustment angle in response to the power of the first calibration signal and the second calibration signal.

12. The system of claim 11, wherein the antenna tower is operable to determine the adjustment angle using a table associating the power of the first calibration signal and the second calibration signal with the adjustment angle.

13. The system of claim 1, wherein:

the antenna tower is operable to determine the adjustment angle using a table having a plurality of entries, each entry specifying a range in a value of the first calibration signal and the second calibration signal and a corresponding adjustment angle.

14. A method for communicating signals, the method comprising:

receiving a first calibration signal from a first location;

receiving a second calibration signal from a second location;

determining an adjustment angle from the first calibration signal and the second calibration signal; and

adjusting a subscriber beam in elevation to reduce cell site interference using the adjustment angle.

15. The method of claim 14, further comprising adjusting the subscriber beam with a precision of at least one-half of one degree.

16. The method of claim 14, further comprising receiving the subscriber beam at approximately three decibels lower than a peak of the subscriber beam by a subscriber at an approximate radius of a cell site serviced by the subscriber beam.

17. The method of claim 14, further comprising generating the subscriber beam using a first antenna and a second antenna of an antenna tower, the first antenna spaced apart from the second antenna in a substantially vertical direction.

18. The method of claim 17, wherein:

the antenna tower is operates at a wavelength; and

the distance between the first antenna and the second antenna is greater than ten wavelengths.

19. The method of claim 17, further comprising generating the subscriber beam using the first antenna, the second antenna, and a third antenna operable to reduce a null of the subscriber beam.

20. The method of claim 19, wherein:

the antenna tower operates at a wavelength; and

the distance between the second antenna and the third antenna is less than one wavelength.

21. The method of claim 14, wherein:

the subscriber beam is generated by a target antenna tower operable to service a target cell site having an approximate radius, the target antenna tower operating at a frequency;

the first location comprises a first antenna tower servicing a first cell site adjacent to the target cell site; and

the second location comprises a second antenna tower operating at the same frequency as the target antenna tower.

22. The method of claim 14, wherein:

the subscriber beam is generated by an antenna tower operable to service a cell site having a radius;

the distance between the antenna tower and the first location is approximately two times the radius; and

the distance between the antenna tower and the second location is approximately four and one-half times the radius.

23. The method of claim 14, further comprising:

monitoring the power of the first calibration signal and the second calibration signal; and

determining the adjustment angle in response to the power of the first calibration signal and the second calibration signal.

24. The method of claim 23, further comprising determining the adjustment angle using a table associating the power of the first calibration signal and the second calibration signal with the adjustment angle.

25. The method of claim 23, further comprising determining the adjustment angle using a table, wherein the table comprises a plurality of entries, each entry specifying a range in a value of the first calibration signal and the second calibration signal and a corresponding adjustment angle.

26. A system for communicating signals, the system comprising:

a first antenna tower operable to transmit a first calibration signal;

a second antenna tower operable to transmit a second calibration signal; and

a target antenna tower operable to receive the first calibration signal and the second calibration signal, to determine an adjustment angle from the first calibration signal and the second calibration signal, and to adjust a subscriber beam in elevation to reduce cell site interference using the adjustment angle.

27. The system of claim 26, wherein the target antenna tower adjusts the subscriber beam with a precision of at least one-half of one degree.

28. The system of claim 26, wherein:

the target antenna tower is located in a target cell site having a radius; and

a subscriber at the approximate radius receives the subscriber beam at approximately three decibels lower than a peak of the subscriber beam.

29. The system of claim 26, wherein:

the target antenna tower comprises a first antenna and a second antenna spaced apart from the first antenna in a substantially vertical direction; and

the first antenna and the second antenna generate the subscriber beam.

30. The system of claim 29, wherein:

the target antenna tower operates at a wavelength; and

the distance between the first antenna and the second antenna is greater than ten wavelengths.

31. The system of claim 29, wherein:

the target antenna tower comprises a third antenna;

the first antenna, the second antenna, and the third antenna generate the subscriber beam; and

the third antenna is operable to reduce a null of the subscriber beam.

32. The system of claim 31, wherein:

the target antenna tower operates at a wavelength; and

the distance between the second antenna and the third antenna is less than one wavelength.

33. The system of claim 26, wherein:

the target antenna tower is located in a target cell site;

the first calibration tower is located in a first calibration cell site adjacent to the target cell site;

the target antenna tower operates at a frequency; and

the second antenna tower operates at the frequency.

34. The system of claim 26, wherein:

the target antenna tower is located in a target cell site having a radius

the distance between the target antenna tower and the first antenna tower is approximately two times the radius; and

the distance between the target antenna tower and the second antenna tower is approximately four and one-half times the radius.

35. The system of claim 26, wherein the target antenna tower comprises a monitor operable to monitor the power of the first calibration signal and the second calibration signal, and to determine the adjustment angle in response to the power of the first calibration signal and the second calibration signal.

36. The system of claim 35, wherein the target antenna tower is operable to generate the adjustment angle using a table associating the power of the first calibration signal and the second calibration signal with the adjustment angle.

37. The system of claim 26, wherein:

the target antenna tower is operable to generate the adjustment angle using a table;

the table is determined from an initial calibration of the target antenna tower; and

the table comprises a plurality of entries, each entry specifying a range in a value of the first calibration signal and the second calibration signal and a corresponding adjustment angle.

* * * * *

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(54) **CHANNEL CARD FOR EXTENDING COVERAGE AREA OF BASE STATION**

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(52) **U.S. Cl.** **455/453**; 455/561

(57) **ABSTRACT**

There is provided a channel card for extending the coverage area of a base station, which controls GPS reference signals provided to base station modems to extend the coverage area by up to four times a general base station coverage area. The channel card includes: a controller for generating control signals for extending the coverage area of the base station; a system clock distributor for dividing a GPS reference signal applied from a GPS clock receiver to generate a plurality of system clocks; a coverage area extending clock generator for converting the GPS reference signal supplied from the GPS clock receiver into a plurality of signals under the control of the controller, to generate clocks for extending the coverage area; a coverage area extending clock controller for selectively providing the plurality of coverage area extending clocks generated by the coverage area extending clock generator to first to fourth base station modems under the control of the controller; and the first to fourth base station modems which operate according to the coverage area controlling clocks provided by the extension clock controller and the system clocks generated by the system clock distributor, to handle calls established in a first area having the minimum coverage area to a fourth area having the maximum coverage area.

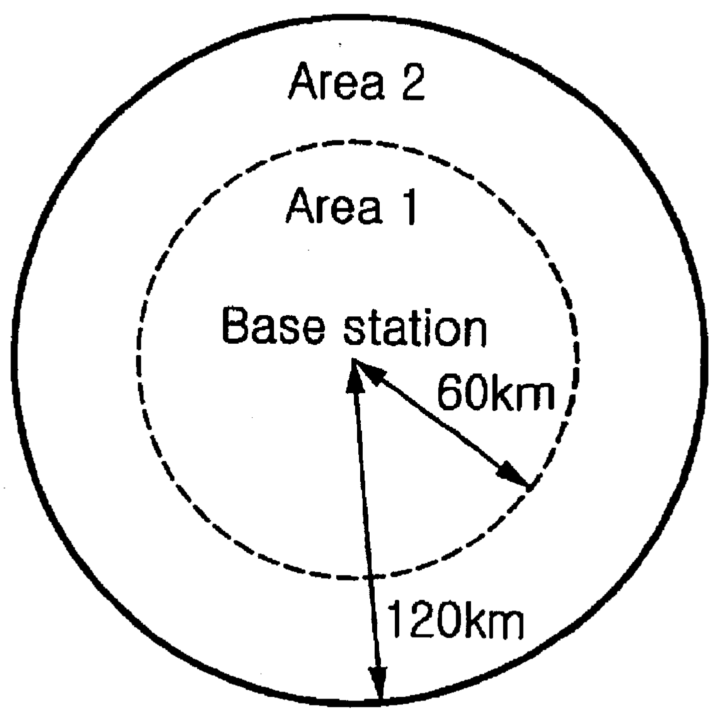


FIG. 1

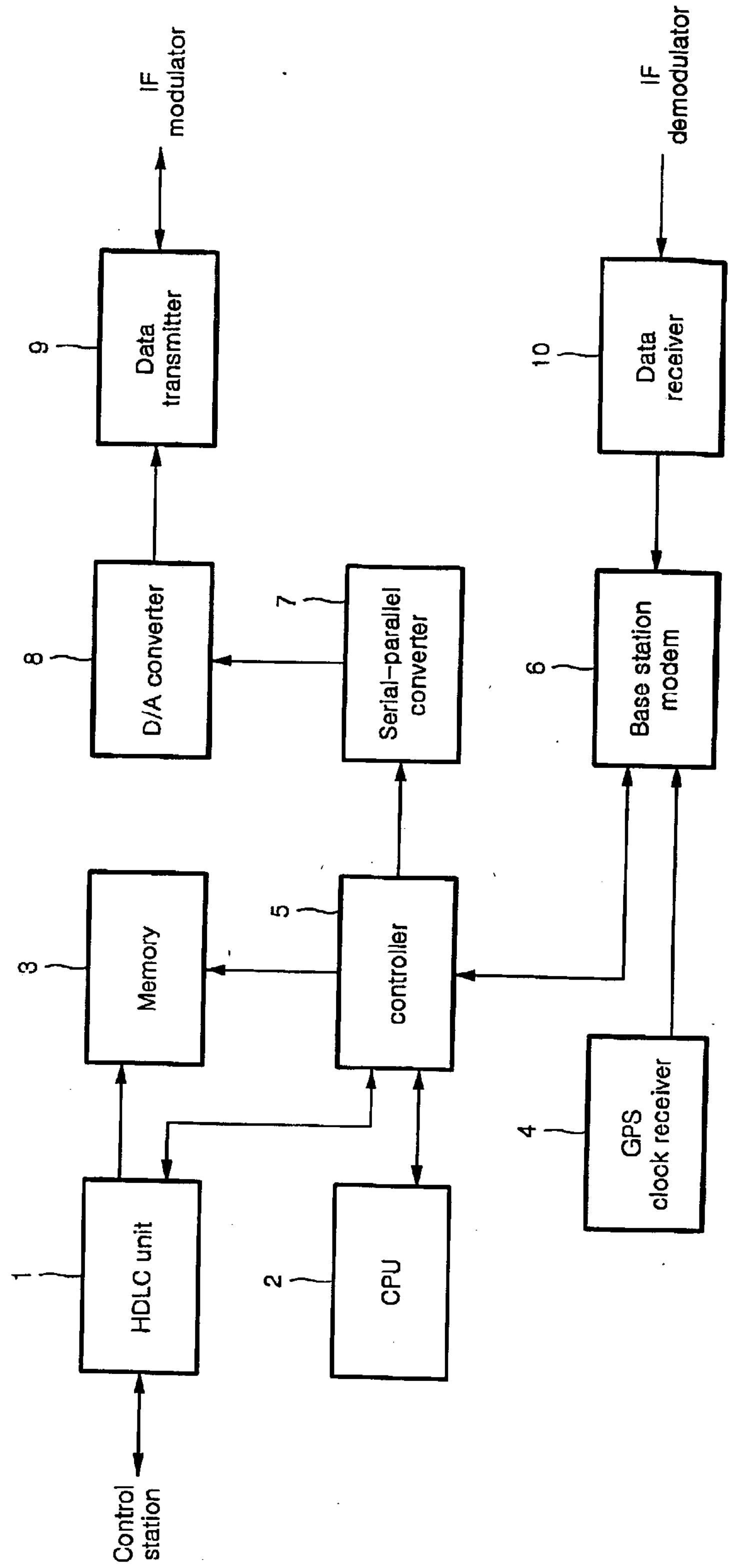

Control station
1
HDLC unit
2
CPU
3
Memory
4
GPS clock receiver
5
controller
6
Base station modem
7
Serial-parallel converter
8
D/A converter
9
Data transmitter
10
Data receiver
IF modulator
IF demodulator

FIG. 2

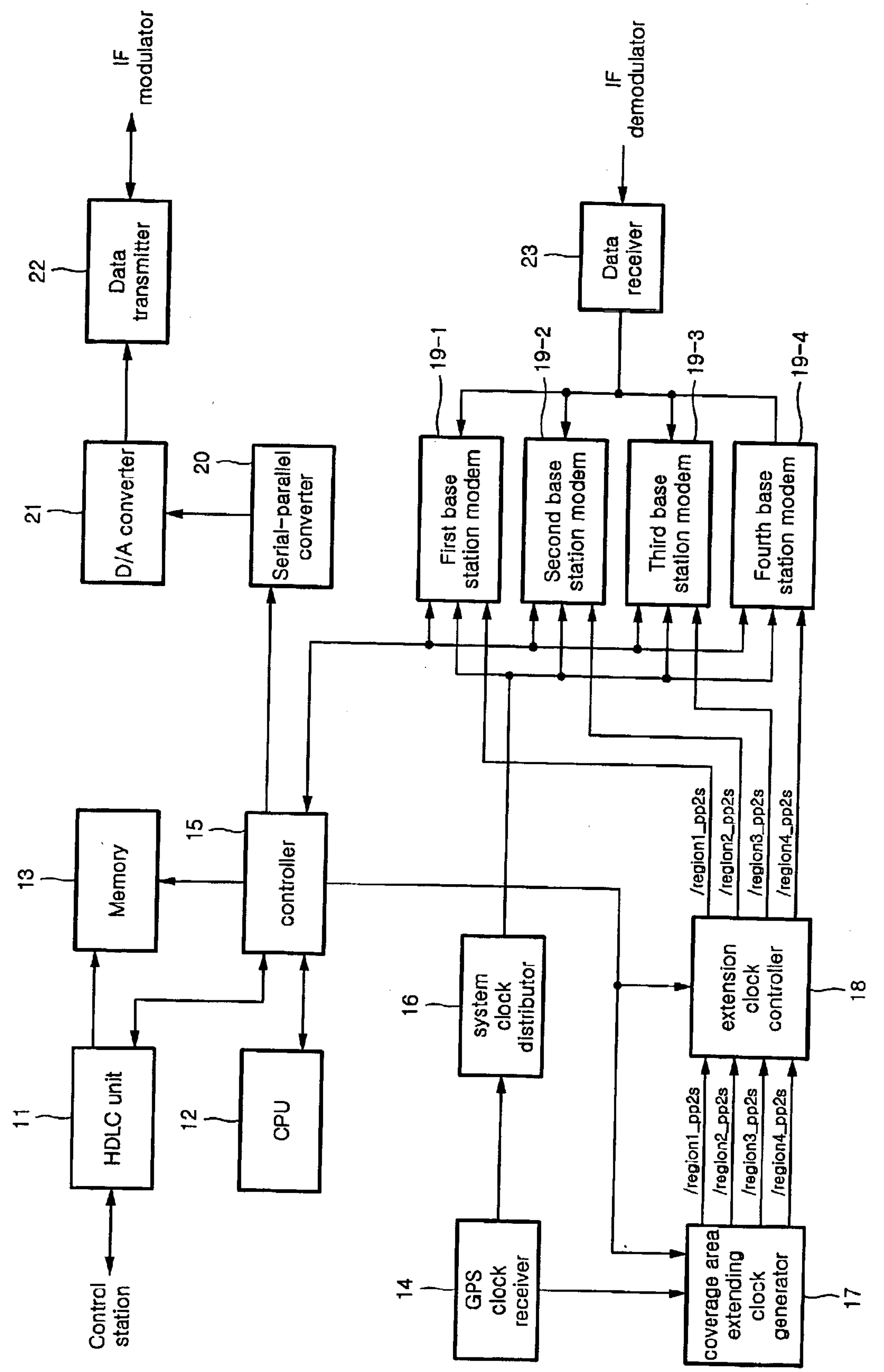

Control station
HDLC unit
11
CPU
12
Memory
13
controller
15
GPS clock receiver
14
system clock distributor
16
coverage area extending clock generator
17
extension clock controller
18
/region1_pp2s
/region2_pp2s
/region3_pp2s
/region4_pp2s
First base station modem
19-1
Second base station modem
19-2
Third base station modem
19-3
Fourth base station modem
19-4
Serial-parallel converter
20
D/A converter
21
Data transmitter
22
IF modulator
Data receiver
23
IF demodulator

FIG. 3

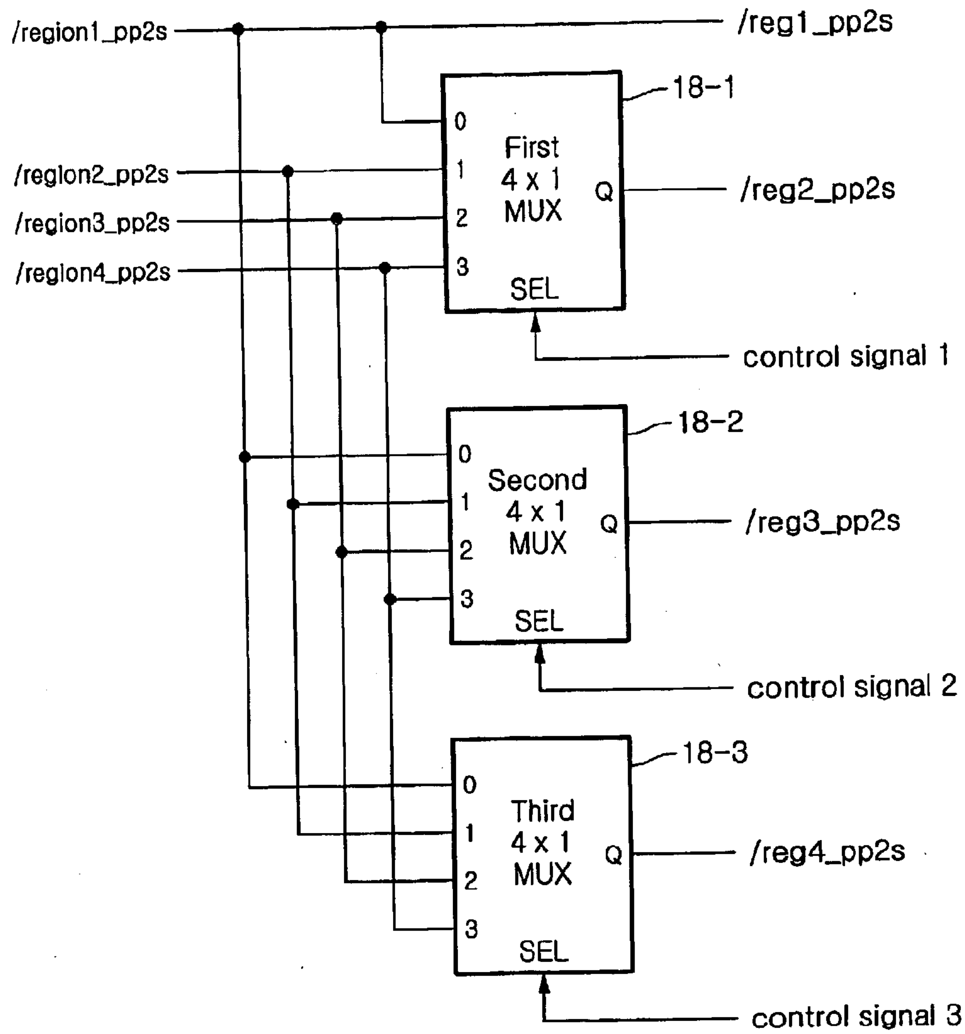

/region1_pp2s
/reg1_pp2s
18-1
0
1
2
3
First
4 x 1
MUX
Q
SEL
/region2_pp2s
/region3_pp2s
/region4_pp2s
/reg2_pp2s
control signal 1
18-2
Second
4 x 1
MUX
/reg3_pp2s
control signal 2
18-3
Third
4 x 1
MUX
/reg4_pp2s
control signal 3

FIG. 4

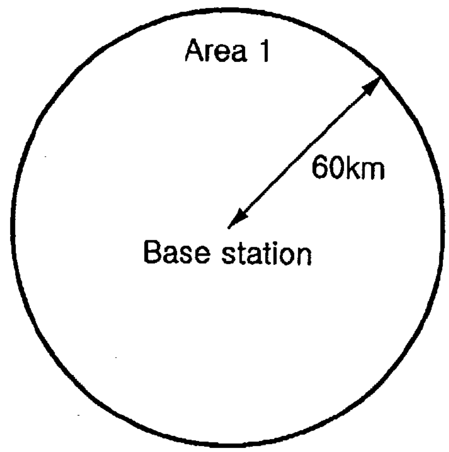

Area 1
60km
Base station

FIG. 5

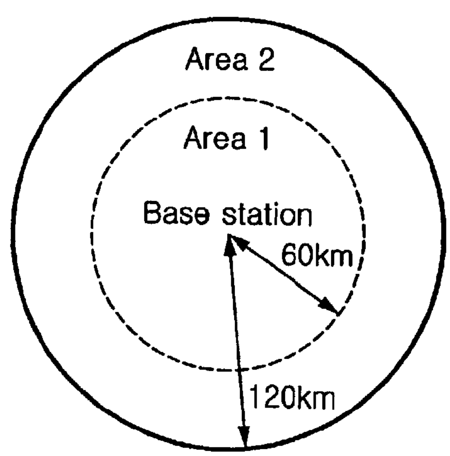
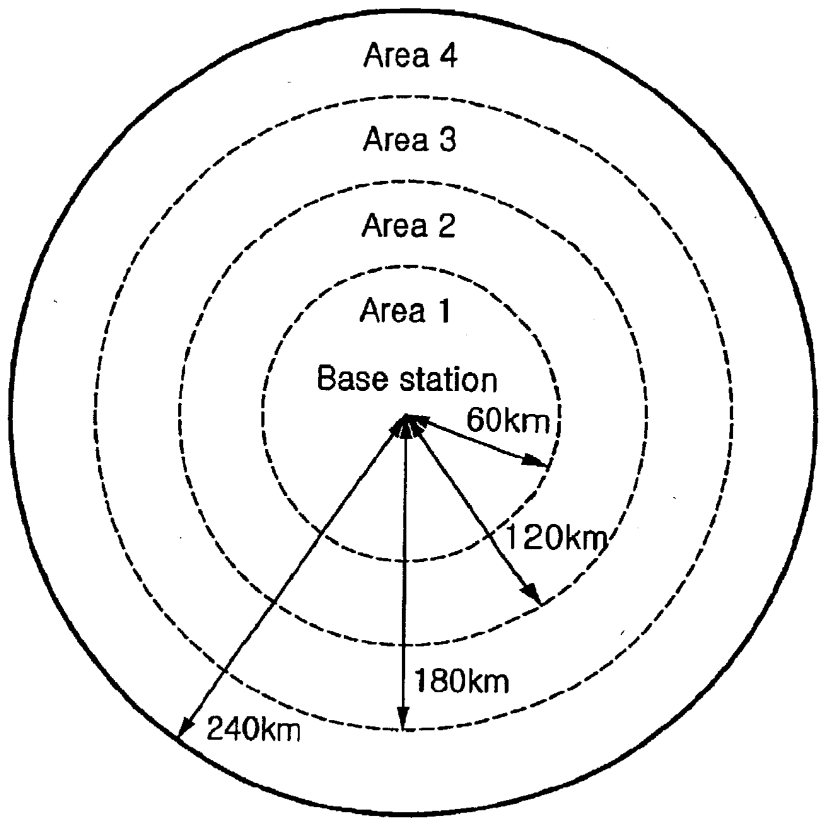

Area 2
Area 1
Base station
60km
120km

FIG. 6


Area 4
Area 3
Area 2
Area 1
Base station
60km
120km
180km
240km

CHANNEL CARD FOR EXTENDING COVERAGE AREA OF BASE STATION

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a channel card for extending the coverage area of a base station. Specifically, the invention relates to a channel card for extending the coverage area of a base station, which controls global positioning system (GPS) reference signals provided to base station modems to extend the coverage area by up to four times a general base station coverage area.

[0003] 2. Description of the Related Art

[0004] The base station of a mobile communication system such as a digital cellular system (DCS) and personal communication system (PCS) generally includes a channel card handling actual calls. This channel card determines the coverage area of the base station on the basis of the modem of the base station. **FIG. 1** shows a conventional base station channel card.

[0005] Referring to **FIG. 1, a** high level data link control (HDLC) unit **1** transmits/receives data to/from a control station, and a CPU **2** controls the entire operation of the base station system. A memory **3** is connected to the HDLC unit **1** and a controller **5** to store control data and generation data. A GPS clock receiver **4** receives clocks sent from a GPS and transmits it to a base station modem **6** which will be described below. The controller **5** is connected to the CPU **2**, HDLC unit **1**, memory **3** and base station modem **6** to control all devices of the channel card under the control of the CPU **2**. The base station modem **6** taking charge of calls is controlled by the controller **5** and operates by a reference clock transmitted from the GPS clock receiver **4**. A data receiver **10** receives data sent from a mobile through an intermediate frequency (IF) demodulator and transmits the data to the base station modem **6**. Further, a serial-parallel converter **7** converts serial data which has passed through the base station modem **6** and controller **5** into parallel data. This parallel data is converted into analog data by a D/A converter **8**. A data transmitter **9** delivers this analog data to an IF modulator to transmit it to the mobile.

[0006] The conventional channel card constructed as above is used for a general base station to cover only regions having the radius of 60 Km. Accordingly, a base station whose coverage area is extended to 120 Km, 180 Km or 240 Km that is twice, three times or four times the 60 Km has to develop and employ a new channel card for extension of its coverage area. That is, the channel card used for the general base station cannot be used for the base station whose coverage area is extended. This requires development of a new channel card for extension of the coverage area. Furthermore, base stations having different coverage areas need different channel cards suitable for their coverage areas, resulting in increase in development costs.

SUMMARY OF THE INVENTION

[0007] It is, therefore, an object of the present invention to provide a channel card for extending the coverage area of a base station, which controls GPS reference signals provided to the modem of the base station to extend the coverage area of the base station by up to four times a general coverage area, being capable of being commonly used for base stations having extended coverage areas as well as the general base station.

[0008] To accomplish the object of the present invention, there is provided a channel card for extending the coverage area of a base station, which includes: a controller for generating control signals for extending the coverage area of the base station;

[0009] a system clock distributor for dividing a GPS reference signal applied from a GPS clock receiver to generate a plurality of system clocks; a coverage area extending clock generator for converting the GPS reference signal supplied from the GPS clock receiver into a plurality of signals under the control of the controller, to generate clocks for extending the coverage area; a coverage area extending clock controller for selectively providing the plurality of coverage area extending clocks generated by the coverage area extending clock generator to first to fourth base station modems under the control of the controller; and the first to fourth base station modems which operate according to the coverage area controlling clocks provided by the extending clock controller and the system clocks generated by the system clock distributor, to handle calls established in a first area having the minimum coverage area to a fourth area having the maximum coverage area.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] **FIG. 1** shows the configuration of a conventional base station channel card;

[0011] **FIG. 2** shows the configuration of a channel card for extension of base station coverage area according to the present invention;

[0012] **FIG. 3** shows an embodiment of an extension clock controller of **FIG. 2**;

[0013] **FIG. 4** shows the coverage area of a general base station that can be realized using the channel card of the present invention; and

[0014] **FIGS. 5 and 6** show the coverage areas of base stations for extending their coverage areas which can be realized using the channel card of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0015] Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

[0016] **FIG. 2** shows the configuration of a channel card for extension of base station coverage area according to the present invention. Referring to **FIG. 2**, the channel card of the present invention includes an HDLC unit **11** for transmitting/receiving data to/from a control station, a CPU **12**, a memory **13** for storing control data and generation data, a GPS clock receiver **14** for receiving clocks sent from a GPS, a controller **5** for controlling all devices constructing the channel card, and a system clock distributor **16** for dividing a GPS reference signal provided by the GPS clock receiver **14** to output the divided ones as a plurality of system clocks. The channel card also has a unit **17** for generating clocks for extending the coverage area of a base station, which converts the GPS reference signal supplied from the GPS clock

receiver **14** into multiple signals to generate a plurality of clocks/region1_p2s, /region2_pp2s, /region3_pp2s and /region4_pp2s for extending the base station coverage area under the control of the controller **5**, and a unit **18** for controlling the clocks for extension of the coverage area, which selectively provides the plurality of coverage area extending clocks generated by the coverage area extending clock generator **17** to a plurality of base station modems **19-1~19-4** under the control of the controller **5**. In addition, the channel card further includes first to fourth base station modems **19-1≈19-4** which operate according to coverage area controlling clocks generated by the extension clock generator **18** and the system clocks outputted from the system clock distributor **16** to handle calls established in a region **1** having the coverage area of 60 Km up to a region **4** having the coverage of 240 Km, a serial-parallel converter **20** for converting serial data outputted from the first to fourth base station modems **19-1≈19-4** into parallel data, a D/A converter **21** for converting the parallel data into analog data, a data transmitter **22** for transmitting the analog data to an IF modulator, and a data receiver **23** for receiving data sent from an IF demodulator to deliver it to the first to fourth base station modems **19-1≈19-4**.

[0017] **FIG. 3** shows the extension clock generator **18** of **FIG. 2** in detail. Referring to **FIG. 3**, the extension clock generator **18** includes a first 4×1 MUX **18-1** for selecting one of the four coverage area extending clocks /regionl_pp2s, /region2_pp2s, /region3_pp2s and /region4_pp2s generated by the coverage area extending clock generator **17** according to a first control signal provided by the controller **15** to send it to the second base station modem **19-2** as a coverage area controlling clock /reg2_pp2s, a second 4×1 MUX **18-2** for selecting one of the four coverage area extending clocks /regionl_pp2s, /region2_pp2s, /region3_pp2s and /region4_pp2s generated by the coverage area extending clock generator **17** according to a second control signal provided by the controller **5** to send it to the third base station modem **19-3** as a coverage area controlling clock /reg3_pp2s, and a third 4×1 MUX **18-3** for selecting one of the four coverage area extending clocks /regionl_pp2s, /region2_pp2s, /region3_pp2s and /region4_pp2s generated by the coverage area extending clock generator **17** according to a third control signal provided by the controller **5** to send it to the fourth base station modem **19-4** as a coverage area controlling clock /reg4_pp2s.

[0018] In addition, the extension clock generator **18** provides the first coverage area extending clock /regionl_pp2s among the fourth extending clocks /regionl-pp2s, /region2_pp2s, /region3_pp2s and /region4_pp2s generated by the coverage area extending clock generator **17** to the first base station modem **19-2** as a coverage area controlling clock /regl_pp2s.

[0019] **FIG. 4** shows the coverage area of a general base station that can be realized using the channel card of the present invention. As shown in **FIG. 4**, the channel card of the invention can cover the coverage area of 60 Km. **FIGS. 5 and 6** show the coverage areas of base stations for extending their coverage areas, which can be realized using the channel card of the present invention. In this case, the channel card of the invention can cover areas extended to 120 Km and 240 Km.

[0020] There will be explained below the operation of the channel card for extending the base station coverage area constructed as above.

[0021] First of all, when data is transmitted to a mobile, the HDLC unit **11** receives data from a control station and generates an interrupt to the CPU **12** through the controller **15**. The CPU **12** analyzes the data inputted from the HDLC unit **11** and sends it to the first to fourth base station modems **19-1≈19-4**. The first to fourth modems **19-1≈19-4** modulate the data received from the CPU **12** according to the system clocks provided by the system clock distributor **16** to send it to the serial-parallel converter **20**. Then, the serial-parallel converter **20** converts the data sent from the modems **19-1≈19-4** into parallel data to transmit it to the D/A converter **21** which converts the parallel data into analog data to deliver it to the data transmitter **22**. The data transmitter **22** sends the analog data to the IF modulator to transmit it to the mobile.

[0022] When the channel card receives data from the mobile, upon reception of digital data from the IF demodulator, the first to fourth base station modems **19-1≈19-4** accept this data, demodulate it and generate an interrupt to the CPU **12** through the controller **15**. Then, CPU **12** reads the data demodulated by the modems **19-1≈19-4** and converts it to meet the HDCL mode and transmits it to the control station through the HDLC unit **11**.

[0023] Next, there is described the operation of the channel card in case of extension of the coverage area. The coverage area extending clock generator **17** converts the GPS reference signal provided by the GPS clock receiver **14** through its inner clock generator to generate four coverage area extending clocks. Specifically, the coverage area extending clock generator generates a first clock /regionl_pp2s used for a general base station having the coverage area of 60 Km, and second, third and fourth clocks /region2_pp2s, /region 3_pp2s and /region4_pp2s used for extending the coverage area to 120 Km, 180 Km and 240 Km, respectively, and applies them to the extension clock controller **18**.

[0024] In case of realization of the general base station having the coverage area of 60 Km, the extension clock controller **18** controls the first clock /regionl_pp2s among the four clocks sent from the coverage area extending clock generator **17** to be sent to the first base station modem **19-1**. Specifically, the extending clock controller **18** directly transmits the first clock /regionl_pp2s among the four clocks /regionl_pp2, /region2_pp2s, /region 3_pp2s and /region4_pp2s as the first coverage area controlling clock /reg_pp2s to the first modem **19-1**. The first, second and third 4×1 MUXs **18-1**, **18-2** and **18-3** select the first clock /regionl_pp2s from the four clocks according to first, second and third control signals of '0' provided by the controller **15** to apply the selected first clock as second, third and fourth coverage area controlling clocks reg2_pp2s, reg3_pp2s and reg4_pp2s to the second, third and fourth modems **19-2**, **19-3** and **19-4**, respectively, thereby sending a first GPS reference signal for covering the coverage area of 60 Km to all of the base station modems.

[0025] In case of realization of the base station having the coverage area extended to 120 Km, as show in **FIG. 5**, the extension clock controller **18** controls the first clock /regionl_pp2s among the four clocks /regionl_pp2,

/region2_pp2s, /region 3_pp2s and /region4_pp2s generated by the coverage area extending clock generator **17** to be applied to the first and second base station modems **19-1** and **19-2** and controls the second extending clock /region2_pp2s to be supplied to the third and fourth modems **19-3** and **19-4**. Specifically, the extension clock controller **18** directly supplies the first clock /region1_pp2s among the four clocks /region1_pp2, /region2_pp2s, /region 3_pp2s and /region4_pp2s to the first modem **19-1** as the first coverage area controlling clock /reg1_pp2s. The first 4×1 MUX **18-1** selects the first clock /region1_pp2s from the four clocks according to the first control signal of '0' provided by the controller **15** to apply it as the second coverage area controlling clocks reg2_pp2s to the second modems **19-2**. The second and third 4×1 MUXs **18-2** and **18-3** select the second coverage area extending clock /region2_pp2s from the four clocks according to second and third control signals of '1' provided by the controller **15** to apply it as third and fourth coverage area controlling clocks reg3_pp2s and reg4_pp2s to the third and fourth modems **19-3** and **19-4**, respectively, thereby sending the first GPS reference signal for covering the coverage area of 60 Km to the first and second base station modems **19-1** and **19-2** and applying a second GPS reference signal for covering the coverage area of 120 Km to the third and fourth modems **19-3** and **19-4**.

[**0026**] In case of realization of the base station having the coverage area extended to 180 Km, as show in **FIG. 6**, the extension clock controller **18** controls the first clock /region1_pp2s among the four clocks /region1_pp2, /region2_pp2s, /region 3_pp2s and /region4_pp2s generated by the coverage area extending clock generator **17** to be applied to the first and second base station modems **19-1** and **19-2**, controls the second extending clock /region2_pp2s to be supplied to the third modem **19-3**, and controls the third clock /region3_pp2s to be applied to the fourth modem **19-4**. Specifically, the extension clock controller **18** directly supplies the first clock /region1_pp2s among the four clocks /region1_pp2, /region2_pp2s, /region 3_pp2s and /region4_pp2s to the first modem **19-1** as the first coverage area controlling clock /reg1_pp2s, and the first 4×1 MUX **18-1** selects the first clock /region1_pp2s from the four clocks according to the first control signal of '0' provided by the controller **15** to apply it as the second coverage area controlling clocks reg2_pp2s to the second modems **19-2**. The second 4×1 MUX **18-2** selects the second coverage area extending clock /region2_pp2s from the four clocks according to the second control signal of '1' provided by the controller **15** to apply it as the third coverage area controlling clocks reg3_pp2s to the third modem **19-3**, and the third 4×1 MUX **18-3** selects the third coverage area extending clock /region3_pp2s from the four clocks according to the third control signal of '2' provided by the controller **15** to apply it as the fourth coverage area controlling clocks reg4_pp2s to the fourth modem **19-4**. By doing so, first GPS reference signal for covering the coverage area of 60 Km is transmitted to the first and second base station modems **19-1** and **19-2**, the second GPS reference signal for covering the coverage area of 120 Km is sent to the third modem **19-3**, and a third GPS reference signal for covering the coverage area of 180 Km is applied to the fourth modem **19-4**.

[**0027**] In case of realization of the base station having the coverage area extended to 240 Km, as show in **FIG. 6**, the extension clock controller **18** controls the four clocks /region1_pp2, /region2_pp2s, /region 3_pp2s and /region4_pp2s generated by the coverage area extending clock generator **17** to be applied to the first to fourth base station modems **19-1** to **19-4**, respectively. Specifically, the extension clock controller **18** directly supplies the first clock /region1_pp2s among the four clocks /region1_pp2, /region2_pp2s, /region 3_pp2s and /region4_pp2s to the first modem **19-1** as the first coverage area controlling clock /reg1_pp2s, and the first 4×1 MUX **18-1** selects the second clock /region2_pp2s from the four clocks according to the first control signal of '1' provided by the controller **15** to apply it as the second coverage area controlling clocks reg2_pp2s to the second modems **19-2**. The second 4×1 MUX **18-2** selects the third coverage area extending clock /region3_pp2s from the four clocks according to the second control signal of '2' provided by the controller **15** to apply it as the third coverage area controlling clocks reg3_pp2s to the third modem **19-3**, and the third 4×1 MUX **18-3** selects the fourth coverage area extending clock /region4_ p2s from the four clocks according to the third control signal of '3' provided by the controller **15** to apply it as the fourth coverage area controlling clocks reg4_pp2s to the fourth modem **19-4**. By doing so, first to fourth GPS reference signals for respectively covering the coverage area of 60 K, 120 Km, 180 Km and 240 Km are transmitted to the first to fourth base station modems **19-1** to **19-4**, respectively.

[**0028**] As described above, the channel card for extending the base station coverage area according to the present invention controls the GPS reference signals supplied to the base station modems to extend the coverage area by up to four times the general coverage area. Accordingly, calls can be established even at a place where installation of the base station is impossible, such as sea, or a place having a small number of users without setup of base stations. Furthermore, costs for installation of base stations can be reduced because the coverage area can be extended without set up of additional base stations. Moreover, a single channel card can be commonly used for base stations having extended coverage areas as well as general base stations so that channel card developing costs can be saved.

What is claimed is:

1. A channel card for extending the coverage area of a base station, which modulates data from a control state according to a GPS clock to transmit it to an IF modulator, and converts data sent from an IF demodulator into HDLC data to transmit it to the control station, the channel card comprising:

- a controller for generating control signals for extending the coverage area of the base station;
- a system clock distributor for dividing a GPS reference signal applied from a GPS clock receiver to generate a plurality of system clocks;
- a coverage area extending clock generator for converting the GPS reference signal supplied from the GPS clock receiver into a plurality of signals under the control of the controller, to generate clocks for extending the coverage area;
- a coverage area extending clock controller for selectively providing the plurality of coverage area extending clocks generated by the coverage area extending clock generator to first to fourth base station modems under the control of the controller; and

the first to fourth base station modems which operate according to the coverage area controlling clocks provided by the extension clock controller and the system clocks generated by the system clock distributor, to handle calls established in a first area having the minimum coverage area to a fourth area having the maximum coverage area.

2. The channel card as claimed in claim 1, wherein the minimum coverage area has the radius of 60 Km and the maximum coverage area has the radius of 240 Km.

3. The channel card as claimed in claim 1, wherein the extension clock controller directly transmits a first clock among the clocks generated by the coverage area extending clock generator to the first base station modem as a first coverage area extending clock.

4. The channel card as claimed in claim 1, wherein the extension clock controller includes a first 4×1 MUS for selecting one of the coverage area extending clocks generated by the coverage area extending clock generator according to a first control signal provided by the controller to transmit it to the second base station modem as a second coverage area controlling clock, a second 4×1 MUS for selecting one of the coverage area extending clocks generated by the coverage area extending clock generator according to a second control signal provided by the controller to transmit it to the third base station modem as a third coverage area controlling clock, and a third 4×1 MUS for selecting one of the coverage area extending clocks generated by the coverage area extending clock generator according to a third control signal provided by the controller to transmit it to the fourth base station modem as a fourth coverage area controlling clock.

5. The channel card as claimed in claim 1, wherein the first, second, third and fourth base station modems handle calls established in areas having the overage areas of 60 Km, 120 Km, 180 Km and 240 Km, respectively.

6. The channel card as claimed in claim 1, wherein the first and second base station modems cover the coverage area of 60 Km and the third and fourth base station modems cover the coverage area of 120 Km under the control of the controller.

7. The channel card as claimed in claim 1, wherein the first and second base station modems handle calls established in the region having the coverage area of 60 Km, the third base station modem processes calls made in the region having the coverage area of 120 Km, and the fourth base station modem handles calls established in the region having the coverage area of 180 Km, under the control of the controller.

8. The channel card as claimed in claim 1, wherein the first base station modem handles calls established in the region having the coverage area of 60 Km, the second base station modem processes calls made in the region having the coverage area of 120 Km, the third base station modem handles calls made in the region having the coverage area of 180 Km, and the fourth base station modem processes calls established in the region having the coverage area of 240 Km, under the control of the controller.

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